WIRELESS

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LEON-G100/G200

Quad Band GSM/GPRS Voice and Data Modules

System Integration Manual

Abstract

This document describes the features and integration of the LEON-G100/G200 Quad Band GSM/GPRS data and voice modules. The LEON-G100/G200 are complete and cost efficient solutions, bringing full feature Quad Band GSM/GPRS data and voice transmission technology in a compact form factor.

29.5 x 18.9 x 2.84 mm

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Preface

u-blox Technical Documentation

As part of our commitment to customer support, u-blox maintains an extensive volume of technical documentation for our products. In addition to our product-specific technical data sheets, the following manuals are available to assist u-blox customers in product design and development.

AT Commands Manual: This document provides the description of the supported AT commands by the LEON GSM/GPRS Voice and Data Modules to verify all implemented functionalities.

System Integration Manual: This Manual provides hardware design instructions and information on how to set up production and final product tests.

Application Note: document provides general design instructions and information that applies to all u-blox Wireless modules. See Section Related documents for a list of Application Notes related to your Wireless Module.

How to use this Manual

The LEON-G100/G200 System Integration Manual provides the necessary information to successfully design in and configure these u-blox wireless modules. For navigating this document please note the following:

This manual has a modular structure. It is not necessary to read it from the beginning to the end. To help in finding needed information, a brief section overview is provided below:

1. System description: This chapter introduces the basics of function and architecture of the wireless modules.

This manual has a modular structure. It is not necessary to read it from the beginning to the end.

The following symbols are used to highlight important information within the manual:

☞ An index finger points out key information pertaining to module integration and performance.

⚠ **A warning symbol indicates actions that could negatively impact or damage the module.**

Questions

If you have any questions about u-blox Wireless Integration, please:

- Read this manual carefully.
- Contact our information service on the homepage http://www.u-blox.com
- Read the questions and answers on our FAQ database on the homepage http://www.u-blox.com

Technical Support

Worldwide Web

Our website (www.u-blox.com) is a rich pool of information. Product information, technical documents and helpful FAQ can be accessed 24h a day.

By E-mail

If you have technical problems or cannot find the required information in the provided documents, contact the nearest of the Technical Support offices by email. Use our service pool email addresses rather than any personal email address of our staff. This makes sure that your request is processed as soon as possible. You will find the contact details at the end of the document.

Helpful Information when Contacting Technical Support

When contacting Technical Support please have the following information ready:

- Module type (e.g. LEON-G100) and firmware version
- Module configuration

- Clear description of your question or the problem
- A short description of the application
- Your complete contact details

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1 System description

1.1 Overview

LEON-G100/G200 GSM/GPRS modules integrate a full-featured Release 99 GSM-GPRS protocol stack, with the following main characteristics.

- Quad band support: GSM 850 MHz, EGSM 900 MHz, DCS 1800 MHz and PCS 1900 MHz
- Power class 4 (33 dBm nominal maximum output power) for GSM/EGSM bands
- Power class 1 (30 dBm nominal maximum output power) for DCS/PCS bands
- GPRS multislot class 10
- All GPRS coding schemes from CS1 to CS4 are supported
- GPRS bit rate: 85.6 kbps (max.), 53.6 kbps (typ.) in down-link; 42.8 kbps (max.), 26.8 kbps (typ.) in up-link
- CS (Circuit Switched) Data calls are supported in transparent/non transparent mode up to 9.6 kbps
- Encryption algorithms A5/1 for GSM and GPRS support
- Bearer service fax Group 3 Class 2.0 support

LEON-G100/G200 modules are Class B Mobile Stations (i.e. the data module can be attached to both GPRS and GSM services, using one service at a time). Network operation modes I to III are supported.

Paging messages for GSM calls can optionally be monitored during GPRS data transfer in not-coordinating network operation mode NOM II-III.

PBCCH/PCCCH logical channels supported, CBCH reception when PBCCH supported.

LEON-G100/G200 modules implement GPRS multi-slot class 10 for data transfer. GPRS class determines the maximum number of timeslots available for upload and download and thus the speed at which data can be transmitted and received: higher classes typically allow faster data transfer rates. GPRS multi-slot class 10 uses a maximum of 4 slots in download (reception) and 2 slots in upload (transmission) with 5 slots in total.

The network automatically configures the number of timeslots used for reception or transmission (voice calls take precedence over GPRS traffic). The network also automatically configures channel encoding (CS1 to CS4).

The maximum GPRS bit rate of the mobile station depends on the coding scheme and number of time slots.

1.2 Architecture

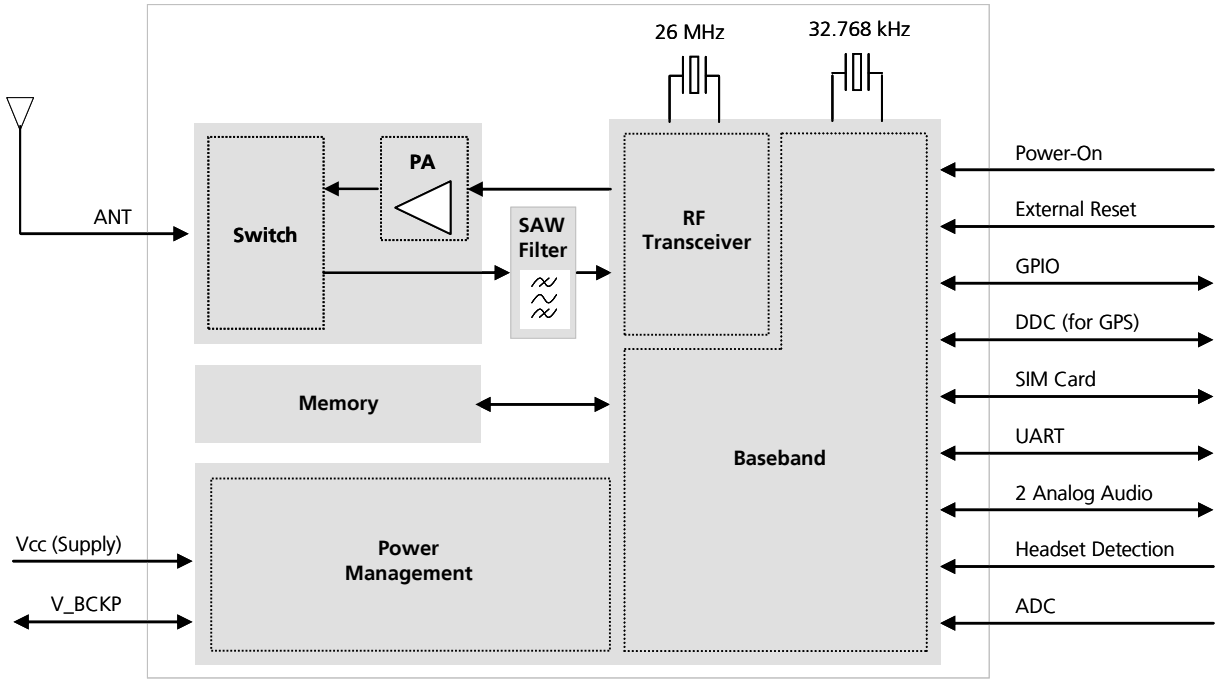

Figure 1: LEON-G100 Block Diagram

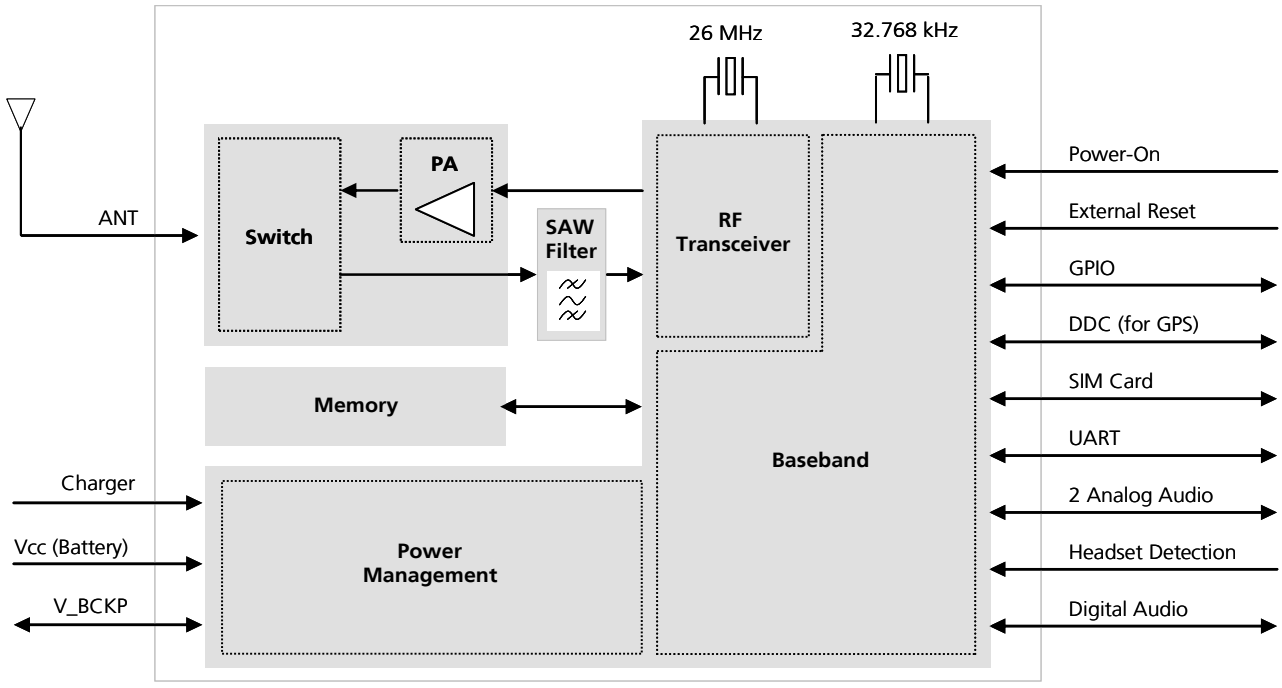

Figure 2: LEON-G200 Block Diagram

1.2.1 Functional blocks

The LEON-G100/G200 modules consist of the following functional blocks:

- RF
- Baseband
- Power Management

1.2.1.1 RF

The RF block is composed of the following main elements:

- RF transceiver (integrated in the GSM/GPRS single chip) performing modulation, up-conversion of the baseband I/Q signals, down-conversion and demodulation of the RF received signals. The RF transceiver includes:
  - Constant gain direct conversion receiver with integrated LNAs;
  - Highly linear RF quadrature demodulator;
  - Digital Sigma-Delta transmitter modulator;
  - Fractional-N Sigma-Delta RF synthesizer;
  - 3.8 GHz VCO;
  - Digital controlled crystal oscillator.
- Transmit module, which amplifies the signals modulated by the RF transceiver and connects the single antenna input/output pin of the module to the suitable RX/TX path, via its integrated parts:
  - Power amplifier;
  - Antenna switch;
- RX diplexer SAW (band pass) filters;
- 26 MHz crystal, connected to the digital controlled crystal oscillator to perform the clock reference in active or connected mode.

1.2.1.2 Baseband

The Baseband block is composed of the following main elements:

- Baseband integrated in the GSM/GPRS single chip, including:
  - Microprocessor;
  - DSP (for GSM/GPRS Layer 1 and audio processing);
  - Peripheral blocks (for parallel control of the digital interfaces);
  - Audio analog front-end;
- Memory system in a multi-chip package integrating two devices:
  - NOR flash non-volatile memory;
  - PSRAM volatile memory;
- 32.768 kHz crystal, connected to the oscillator of the RTC to perform the clock reference in idle or power-off mode.

1.2.1.3 Power Management

The Power Management block is composed of the following main elements:

- Voltage regulators integrated in the GSM/GPRS single chip for direct connection to battery;
- Charging control circuitry.

1.2.2 Hardware differences between LEON-G100 and LEON-G200

Hardware differences between the LEON-G100 and the LEON-G200 modules:

- Charging control circuitry is available on the LEON-G200 module only

- ADC input is provided on the LEON-G100 module only

1.3 Pin-out

Table 1 describes the pin-out of LEON-G100/G200 modules, with pins grouped by function.

Function	Pin	No	I/O	Description	Remarks
Power	**VCC**	50	I	Module Supply	Clean and stable supply is required: low ripple and low voltage drop must be guaranteed. Voltage provided has to be always above the minimum limit of the operating range. Consider that there are large current spike in connected mode, when a GSM call is enabled. See section 1.5.2
	GND	1, 3, 6, 7, 8, 17, 25, 36, 45, 46, 48, 49	N/A	Ground	GND pins are internally connected but good (low impedance) external ground can improve RF performances.
	V_BCKP	2	I/O	Real Time Clock supply	V_BCKP = 2.0 V (typical) generated by the module to supply Real Time Clock when VCC supply voltage is within valid operating range. See section 1.5.4
	VSIM	35	O	SIM supply	SIM supply automatically generated by the module. See section 1.10
	V_CHARGE - (LEON-G200)	4	I	Charger voltage supply input	**V_CHARGE and CHARGE_SENSE must be externally connected.** The external supply used as charging source must be voltage and current limited. See section 1.5.3
	CHARGE_SENSE (LEON-G200)	5	I	Charger voltage measurement input	**V_CHARGE and CHARGE_SENSE must be externally connected.** The external supply used as charging source must be voltage and current limited. See section 1.5.3
RF	**ANT**	47	I/O	RF antenna	50 Ω nominal impedance. See section 1.8
Audio	**HS_DET**	18	I	Headset detection input	See section 1.9.1.3
	I2S_WA (LEON-G200)	26	O	I2S word alignment	I2S Interface: see section 1.9.2. Check device specifications to ensure compatibility of supported modes to LEON-G100/G200 module. Add a test point to provide access to the pin for debugging.
	I2S_TXD (LEON-G200)	27	O	I2S transmit data	I2S Interface: see section 1.9.2. Check device specifications to ensure compatibility of supported modes to LEON/G200 module. Add a test point to provide access to the pin for debugging.
	I2S_CLK (LEON-G200)	28	O	I2S clock	I2S Interface: see section 1.9.2. Check device specifications to ensure compatibility of supported modes to LEON/G200 module. Add a test point to provide access to the pin for debugging.
	I2S_RXD (LEON-G200)	29	I	I2S receive data	I2S Interface: see section 1.9.2. Check device specifications to ensure compatibility of supported modes to LEON/G200 module. Add a test point to provide access to the pin for debugging.
	HS_P	37	O	Low power single-ended analog audio output	Audio output used in handset or in headset mode. Audio pin: see section 1.9.1
	SPK_P	38	O	High power differential analog audio output	Audio output used in ring tones or in hands free mode. Audio pin: see section 1.9.1
	SPK_N	39	O	High power differential analog audio output	Used in ring tones or in hands free mode. Audio pin: see section 1.9.1
	MIC_BIAS2	41	I	Second microphone analog bias	Single ended supply output and signal input for the second microphone. Used in headset mode.

Function	Pin	No	I/O	Description	Remarks
					Audio pin: see section 1.9.1
	MIC_GND2	42	I	Second microphone analog reference	Local ground of second microphone. Audio pin: see section 1.9.1
	MIC_GND1	43	I	First microphone analog reference	Local ground of the first microphone. Audio pin: see section 1.9.1
	MIC_BIAS1	44	I	First microphone analog bias	Single ended supply output and signal input for first microphone. Used in handset or in hands free mode. Audio pin: see section 1.9.1
SIM	**SIM_CLK**	32	O	SIM clock	SIM interface: see section 1.10. Must meet SIM specifications
	SIM_IO	33	I/O	SIM data	SIM interface: see section 1.10. Must meet SIM specifications
	SIM_RST	34	O	SIM reset	SIM interface: see section 1.10. Must meet SIM specifications
UART	**DSR**	9	O	UART data set ready	See section 1.11.1. Control convention of the pins
	RI	10	O	UART ring indicator	See section 1.11.1. Control convention of the pins
	DCD	11	O	UART data carrier detect	See section 1.11.1. Control convention of the pins
	DTR	12	I	UART data terminal ready	See section 1.11.1. Control convention of the pins
	RTS	13	I	UART ready to send	See section 1.11.1. Control convention of the pins
	CTS	14	O	UART clear to send	See section 1.11.1. Control convention of the pins
	TxD	15	I	UART transmitted data	See section 1.11.1. Control convention of the pins
	RxD	16	O	UART received data	See section 1.11.1. Control convention of the pins
DDC	**SCL**	30	O	I2C bus clock line	**Fixed open drain. External pull-up required.** See section 1.11.2
	SDA	31	I/O	I2C bus data line	**Fixed open drain. External pull-up required.** See section 1.11.2
ADC	**ADC1 (LEON-G100)**	5	I	ADC input	Resolution: 12 bits. See section 1.12; consider that the impedance of this input changes depending on the operative mode
GPIO	**GPIO1**	20	I/O	GPIO	See section 1.13. Add a test point to provide access to the pin for debugging.
	GPIO2	21	I/O	GPIO	See section 1.13
System	**PWR_ON**	19	I	Power-on input	**PWR_ON pin has high input impedance. Do not keep floating in noisy environment: external pull-up required.** See section 1.6.1
	RESET_N	22	I	External reset input	See section 1.6.3
Reserved	**Reserved**	23			Do not connect
	Reserved	24			Do not connect
	Reserved	40			Do not connect
	Reserved (LEON-G100)	4			Do not connect
	Reserved (LEON-G100)	26			Do not connect. Add a test point to provide access to the pin for debugging.
	Reserved (LEON-G100)	27			Do not connect. Add a test point to provide access to the pin for debugging.
	Reserved (LEON-G100)	28			Do not connect. Add a test point to provide access to the pin for debugging.
	Reserved (LEON-G100)	29			Do not connect. Add a test point to provide access to the pin for debugging.

Table 1: LEON-G100/G200 pinout

1.4 Operating Modes

LEON-G100/G200 modules include several operating modes, each have different active features and interfaces. Table 2 summarizes the various operating modes and provides general guidelines for operation.

General Status	Operating Mode	Description	Features / Remarks
Power-down	Not-Powered Mode	VCC supply not present or below normal operating range. Microprocessor not operating. RTC only operates if supplied through V_BCKP pin.	Module is switched off. Module cannot be switched on by a falling edge provided on the PWR_ON input, neither by a preset RTC alarm, or a rising edge to a valid voltage for charger detection provided on the V_CHARGE and CHARGE_SENSE inputs. Application interfaces not accessible. Internal RTC timer operates only if a valid voltage is applied to V_BCKP pin. Any external signal connected to UART I/F, I2S I/F, HS_DET, or a GPIO must be set low or tri-stated to avoid an increase of module power-off consumption.
	Power-Off Mode	VCC supply within normal operating range. Microprocessor not operating. Only RTC runs.	Module is switched off: normal shutdown after sending the AT+CPWROFF command (refer to u-blox AT Commands Manual [2]). Module can be switched on by a falling edge provided on the PWR_ON input, by a preset RTC alarm, or by a rising edge to a valid voltage for charger detection provided on the V_CHARGE and CHARGE_SENSE inputs. Application interfaces are not accessible. Only the internal RTC timer in operation. Any external signal connected to the UART I/F, I2S I/F, HS_DET pin, or a GPIO must be set low or tri-stated to avoid an increase of the module power-off consumption.
Normal operation	Idle-Mode	Microprocessor runs with 32 kHz as reference oscillator. Module does not accept data signals from an external device.	Module is switched on and is in idle mode (i.e. power saving / sleep mode). Application interfaces disabled. Module by default automatically enters idle mode whenever possible, unless this mode is disabled by appropriate AT command (refer to u-blox AT Commands Manual [2]). If module is registered with the network, it automatically enters idle mode and periodically wakes up to active mode to monitor the paging channel for the paging block reception according to network indication. If module is not registered with the network, it automatically goes in idle mode and periodically wakes up to monitor external activity. Module wakes up from default idle mode to active mode if an RTC alarm occurs. Module wakes up from default idle mode to active mode when data received on UART interface with HW flow control enabled. Module wakes up from default idle mode to active mode if a voice or data call incoming. Module wakes up from default idle mode to active mode when the RTS input line is set to the ON state by the DTE if the AT+UPSV=2 command is sent to the module (feature not enabled by default). The hardware flow control output (CTS line) indicates when the module is in idle (power saving mode): the line is driven in the OFF state when the module is not prepared to accept data signals.
	Active-Mode	Microprocessor runs with 26 MHz as reference oscillator. The module is prepared to accept data signals from an external device.	Module is switched on and is fully active: power saving is not enabled. The application interfaces are enabled.

General Status	Operating Mode	Description	Features / Remarks
	Connected-Mode	Voice or data call enabled. Microprocessor runs with 26 MHz as reference oscillator. Module is prepared to accept data signals from an external device.	The module is switched on and a voice call or a data call (GSM/GPRS) is in progress. Module is fully active. Application interfaces are enabled. When call terminates, module returns to the last operating state (Idle or Active).
Charging (LEON-G200 only)	Pre-charge mode	Battery connected to VCC. Battery voltage level is below the VCC normal operating range. Charger connected to V_CHARGE and CHARGE_SENSE inputs with proper voltage and current characteristics. Charging of the deeply discharged battery is enabled while the module is switched off.	Module is switched off and cannot be switched on (not powered mode). The Pre-Charge phase of the charging process is enabled: charging of the deeply discharged battery is forced by HW at slow current while the module is switched off
	Charge-mode	Battery connected to VCC. Battery voltage level is within the VCC normal operating range. Charger connected to V_CHARGE and CHARGE_SENSE inputs with proper voltage and current characteristics. Charging process enabled while the module is switched on and normal operations are enabled.	Module is switched on and normal operations are enabled (Idle mode, Active mode or Connected mode). The charging process is enabled: charging of battery is controlled by the microprocessor while the module is switched on

Table 2: Module operating modes summary

1.5 Power management

1.5.1 Power supply circuit overview

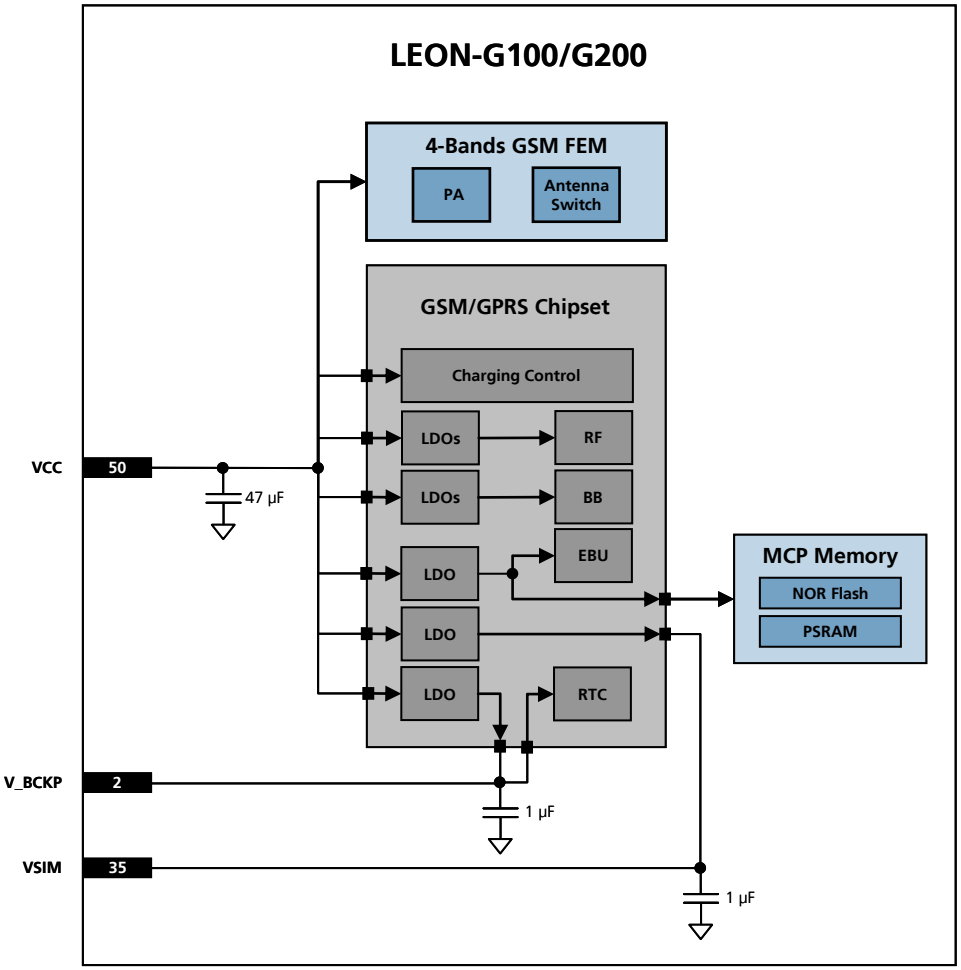

Figure 3: Power supply concept

LEON G100 / LEON-G200 modules are supplied via the **VCC** pin. There is only one main power supply pin.

The VCC pin connects the RF Power Amplifier and the integrated power management unit within the module: all supply voltages needed by the module are generated from the VCC supply by integrated voltage regulators.

When the VCC voltage is within the valid operating range, the module supplies the Real Time Clock. If the VCC voltage is under the minimum operating limit, the Real Time Clock can be externally supplied via the **V_BCKP** pin.

When a 1.8 V or a 3 V SIM card type is connected, LEON G100 / LEON-G200 automatically supply the SIM card via the **VSIM** pin. Activation and deactivation of the SIM interface with automatic voltage switch from 1.8 to 3 V is implemented, in accordance to the ISO-IEC 78-16-e specifications.

The integrated power management unit also provides the control state machine for system start up, including start up with discharged batteries, pre-charging and system reset control.

LEON-G100 / LEON-G200 feature a power management concept optimized for most efficient use of battery power. This is achieved by hardware design utilizing power efficient circuit topology, and by power management software controlling the power saving mode of the module. Battery management runs in the context of the operation and maintenance process:

- Battery charging control, in order to maintain the full capacity of the battery

- Collecting and processing of measurements of battery voltage

1.5.2 Voltage supply (VCC)

LEON G100 / LEON-G200 modules must be supplied through the **VCC** pin by a DC power supply. Voltages must be stable, due to the surging consumption profile of the GSM system (described in the section 1.5.2.1). The DC power supply can be selected from:

- A switching regulator with appropriate power capabilities, low output ripple, and with a switching frequency greater or equal to 1 MHz
- An LDO linear regulator with appropriate power capabilities and with proper power dissipation
- A rechargeable Li-Ion battery with a capacity from 500 mAh up to 1100 mAh (recommended)
- A primary (not rechargeable) battery with appropriate power capabilities

The voltage provided to the **VCC** pin must be within the normal operating range limits specified in the LEON-G100/G200 Data Sheet [1]. Complete functionality of the module is only guaranteed within the specified minimum and maximum VCC voltage range.

☞ Ensure that the input voltage at the **VCC** is above the normal operating range minimum limit to enable the switch-on of the module. Note that the module cannot be switched on if the VCC voltage value is below the minimum specified limit. See LEON-G100/G200 Data Sheet [1].

When the LEON G100 / LEON-G200 modules are in operation, the voltage provided to the VCC pin can exceed the normal operating range limits but must be within the extended operating range limits specified in the LEON-G100/G200 Data Sheet [1]. Module reliability is only guaranteed within the specified operational extended voltage range.

☞ Ensure that the input voltage at the VCC pin never drops below the extended operating range minimum limit when the module is switched on, not even during a GSM transmit burst, where the current consumption can rise up to maximum peaks of 2.5 A in case of a mismatched antenna load. Note that the module switches off when the VCC voltage value drops below the minimum limit.

☞ Operation above the extended operating range maximum limit is not recommended and extended exposure beyond it may affect device reliability.

☞ Stress beyond the VCC absolute maximum ratings may cause permanent damage to the module: if necessary, voltage spikes beyond VCC absolute maximum ratings must be limited to values within the specified boundaries by using appropriate protection.

When designing the power supply for the application, pay specific attention to power losses and transients:

- do not exceed 200 mV voltage drops during transmit bursts
- avoid undershoot and overshoot on voltage drops at the start and at the end of a transmission
- minimize voltage ripple on the supply

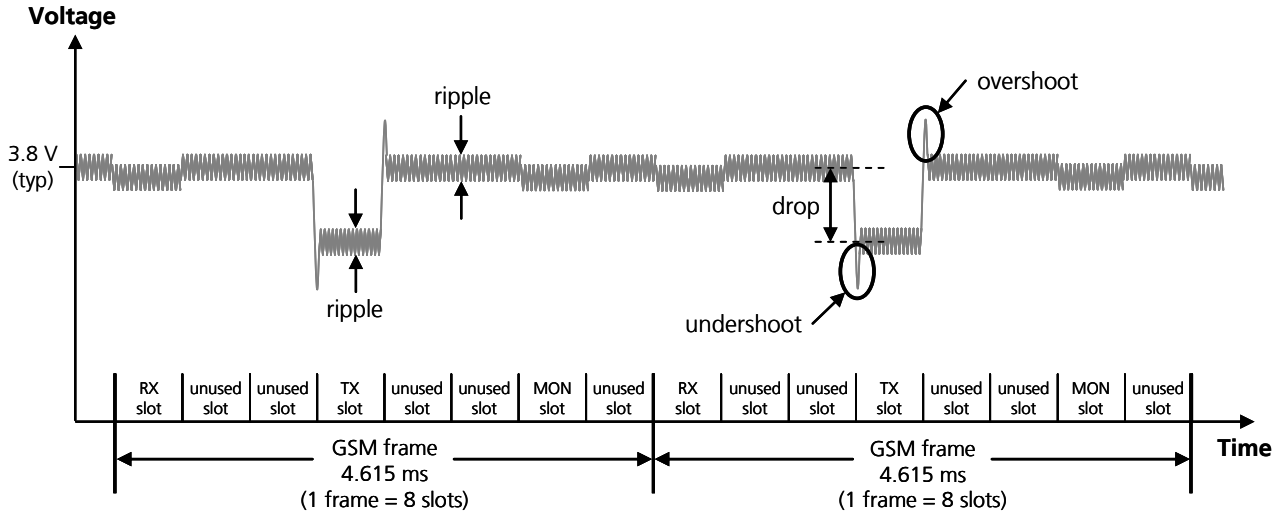

Figure 4: Description of the VCC voltage profile versus time during a GSM call

To reduce voltage drops, use a low impedance power source. The resistance of the power supply lines (connected to VCC and GND pins of the module) on the application board and battery pack should also be considered and minimized: cabling and routing must be as short as possible in order to minimize power losses.

To avoid undershoot and overshoot on voltage drops at the start and at the end of a transmit burst during a GSM call (when current consumption on the VCC supply can rise up to 2.5 A in the worst case), place a 330 µF low ESR capacitor (e.g. KEMET T520D337M006ATE045) located near the **VCC** pin of LEON-G100/G200 board.

To reduce voltage ripple and noise, place near the **VCC** pin of the LEON-G100/G200 board the following:

- 100 nF capacitor (e.g Murata GRM155R61A104K) and a 10 nF capacitor (e.g. Murata GRM155R71C103K) to filter digital logic noises from clocks and data sources
- 10 pF capacitor (e.g. Murata GRM1555C1E100J) to filter transmission EMI in the DCS/PCS bands,
- 39 pF capacitor (e.g. Murata GRM1555C1E390J) to filter transmission EMI in the GSM/EGSM bands.

☞ Any degradation in the power supply performance, due to losses, noise or transients, will directly affect the RF performance of the module since the single external DC power source indirectly supplies all the digital and analog interfaces, and also directly supplies the RF power amplifier (PA).

If the module is supplied by a battery, do not connect any other power supply at the **VCC** supply pin in parallel to the battery.

If the module is not supplied by a battery, Figure 5 and the components listed in Table 3 show an example of a power supply circuit. This example is implemented on the Evaluation Board EVK-G25P. **VCC** supply is provided by a step-down switching regulator with a 1 MHz switching frequency.

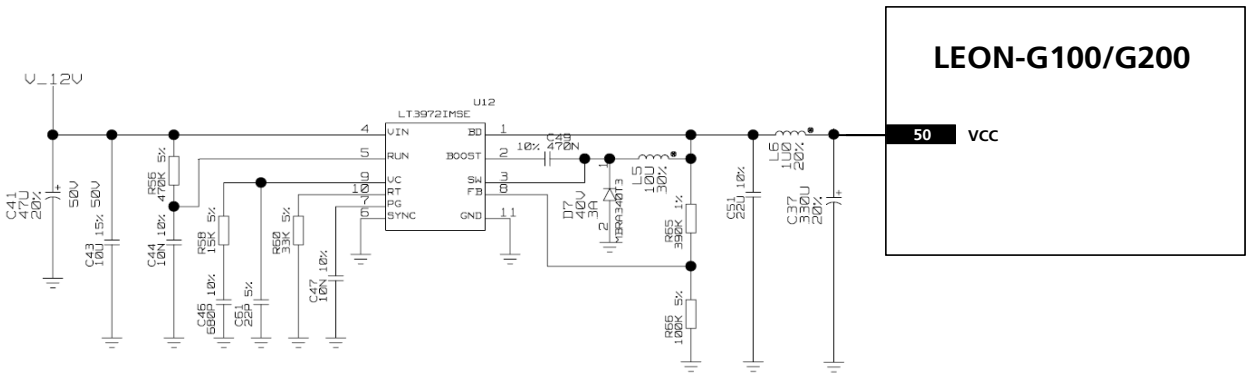

Figure 5: Suggested schematic design for the VCC voltage supply application circuit using a step-down regulator

Reference	Description	Part Number - Manufacturer
C37	330 µF Capacitor Tantalum D_SIZE 6.3 V 45 mΩ	T520D337M006ATE045 - KEMET
C41	47 µF Capacitor Aluminum 0810 50 V	MAL215371479E3 - Vishay
C43	10 µF Capacitor Ceramic X7R 5750 15% 50 V	C5750X7R1H106MB - TDK
C44	10 nF Capacitor Ceramic X7R 0402 10% 16 V	GRM155R71C103KA01 - Murata
C46	680 pF Capacitor Ceramic X7R 0402 10% 16 V	GRM155R71H681KA01 - Murata
C47	10 nF Capacitor Ceramic X7R 0402 10% 16 V	GRM155R71C103KA01 - Murata
C49	470 nF Capacitor Ceramic X7R 0603 10% 25 V	GRM188R71E474KA12 - Murata
C51	22 µF Capacitor Ceramic X5R 1210 10% 25 V	GRM32ER61E226KE15 - Murata
C61	22 pF Capacitor Ceramic COG 0402 5% 25 V	GRM1555C1H220JZ01 - Murata
D7	Schottky Diode 40V 3 A	MBRA340T3G - ON Semiconductor
L5	10 µH Inductor 744066100 30% 3.6 A	744066100 - Wurth Electronics
L6	1 µH Inductor 7445601 20% 8.6 A	7445601 - Wurth Electronics
R56	470 kΩ Resistor 0402 5% 0.1 W	2322-705-87474-L - Yageo
R58	15 kΩ Resistor 0402 5% 0.1 W	2322-705-87153-L - Yageo
R60	33 kΩ Resistor 0402 5% 0.1 W	2322-705-87333-L - Yageo
R65	390 kΩ Resistor 0402 1% 0.063 W	RC0402FR-07390KL - Yageo
R66	100 kΩ Resistor 0402 5% 0.1 W	2322-705-70104-L - Yageo
U12	Step Down Regulator MSOP10 3.5 A 2.4 MHz	LT3972IMSE#PBF - Linear Technology

Table 3: Suggested components for the VCC voltage supply application circuit using a step-down regulator

If another step-down switching regulator is used, the switching frequency must be set to 1 MHz or upper values to avoid a degradation of the RF modulation spectrum performance.

An LDO linear voltage regulator can be used to supply the module. Ensure proper power dissipation on the regulator in order to avoid reaching LDO thermal limits during the high current peak generated by the module during a GSM transmit burst.

1.5.2.1 Current consumption profiles

During operation, the current drawn by the LEON-G100/G200 through the **VCC** pin can vary by some orders of magnitude. This ranges from the high peak of current consumption during the GSM transmitting bursts at maximum power level in connected mode, to the low current consumption during power saving in idle mode.

1.5.2.1.1 Connected-mode

When a GSM call is established, the battery is discharged at a rate determined by the current consumption profile typical of the GSM transmitting and receiving bursts.

The peak of current consumption during a transmission slot is strictly dependent on the transmitted power, which is regulated by the network. If the module is transmitting in GSM talk mode in the GSM 850 or in the EGSM 900 band at the maximum RF power control level 5 (that is approximately 2 W or 33 dBm), the battery discharge current is modulated at up to 2500 mA (worst case value) with pulses of 576.9 µs (width of 1 slot/burst) that occur every 4.615 ms (width of 1 frame = 8 slots) according to GSM TDMA.

During a GSM call, current consumption is about 100 mA in receiving or in monitor bursts and is about 30-50 mA in the inactive unused bursts (low current period). The more relevant contribution to determine the average current consumption is set by the transmitted power in the transmit slot.

An example of current consumption profile of the data module in GSM talk mode is shown in Figure 6.

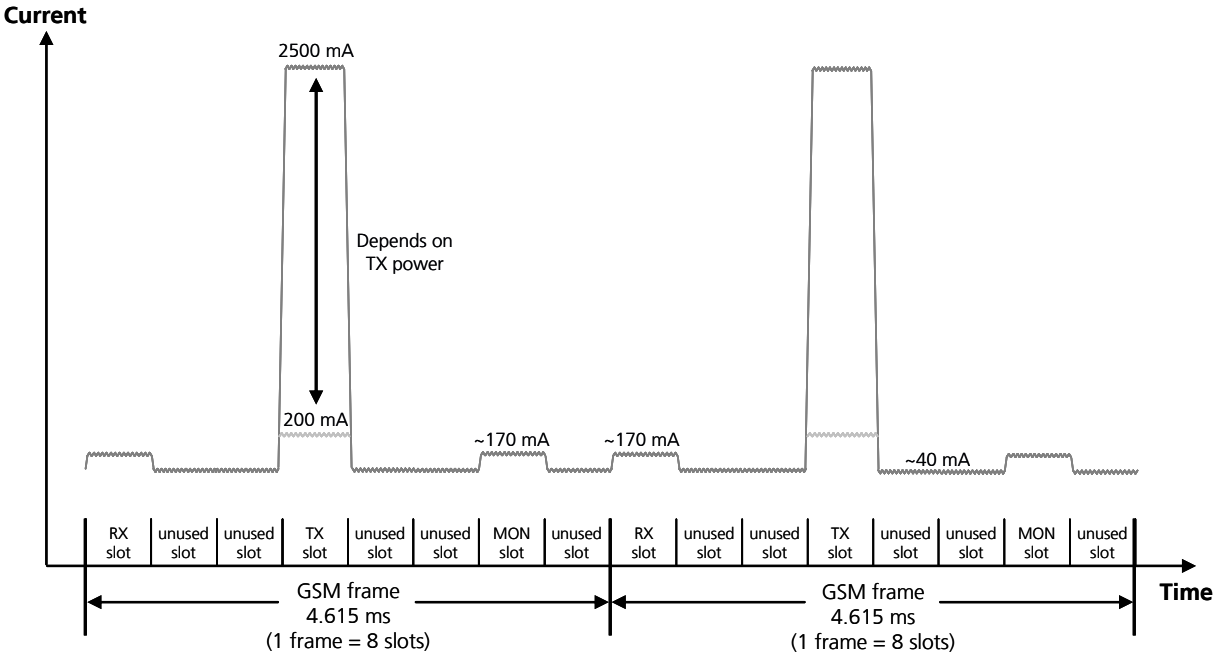

Figure 6: Description of the VCC current consumption profile versus time during a GSM call

When a GPRS connection is established, the battery is discharged at a rate determined by the current consumption profile typical of the GPRS transmitting and receiving bursts. In contrast to a GSM call, during a GPRS connection more than one slot can be used to transmit and/or more than one slot can be used to receive. The transmitted power depends on network conditions and sets the peak of current consumption, but following the GPRS specifications the maximum transmitted power can be reduced if more than one slot is used to transmit, so the maximum peak of current consumption is not as high as can be the case in a GSM call.

1.5.2.1.2 Idle-mode

By default the module automatically enters idle-mode (power-saving mode) whenever possible, unless idle mode is disabled using the appropriate AT command (refer to u-blox AT Commands Manual [2]).

When the data module is registered or attached to a network and a voice or data call is not enabled, the module must periodically monitor the paging channel of the current base station (paging block reception), in accordance to GSM system requirements. When the module monitors the paging channel, it wakes up to active mode, to enable the paging block reception. In between, the module switches to idle-mode (power-saving mode). This is known as GSM discontinuous reception (DRX).

The module processor core is activated during the paging block reception, and automatically switches its reference clock frequency from the 32 kHz to the 26 MHz used in active-mode.

The time period between two paging block receptions is defined by the network. The time interval between two paging block receptions can be from 470.76 ms (width of 2 GSM multiframes = 2 x 51 GSM frames = 2 x 51 x 4.615 ms) up to 2118.42 ms (width of 9 GSM multiframes = 9 x 51 frames = 9 x 51 x 4.615 ms): this is the paging period parameter broadcast and fixed by the base station.

An example of current consumption profile of the data module is shown in Figure 7: the module is registered with the network, automatically goes into idle mode and periodically wakes up to active mode to monitor the paging channel for paging block reception

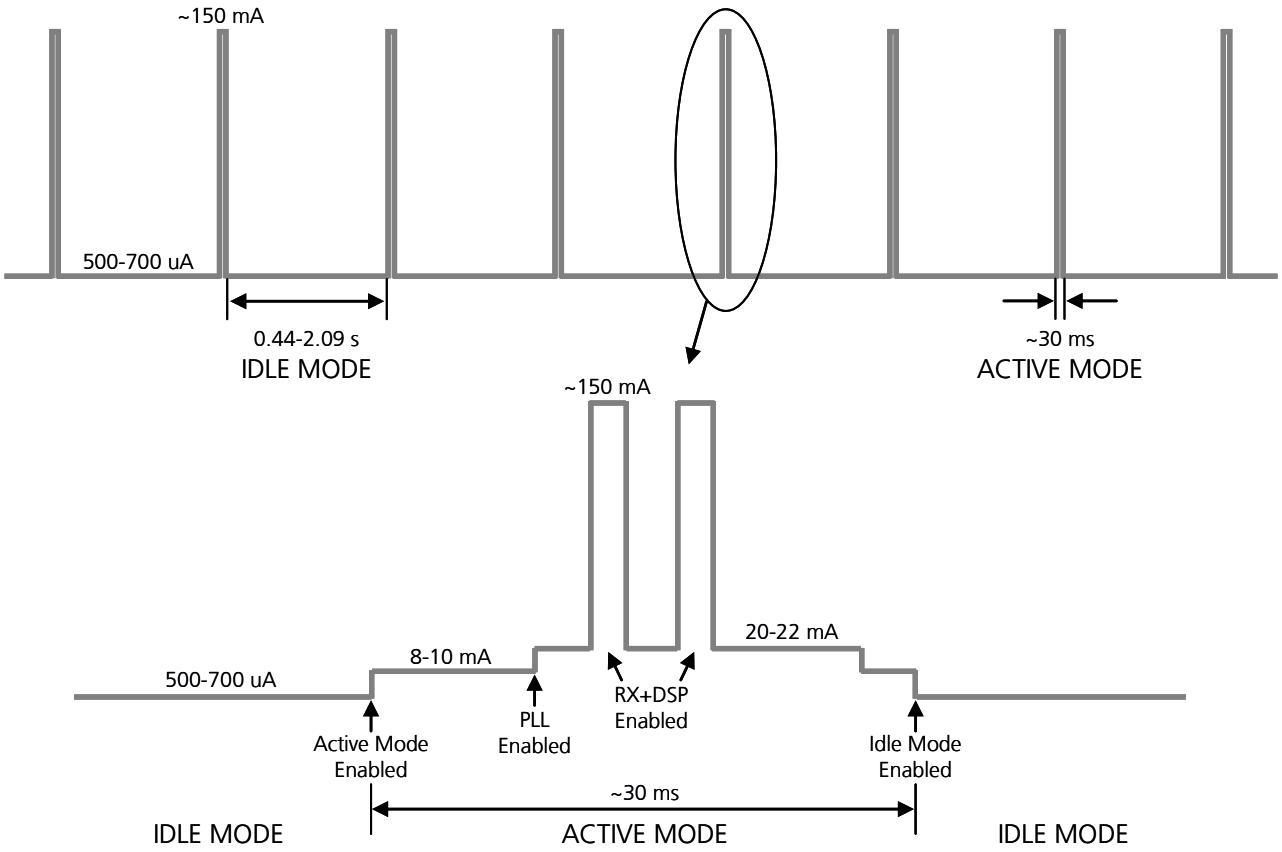

Figure 7: Description of the VCC current consumption profile versus time when the module is registered with the network: the module is in idle mode and periodically wakes up to active mode to monitor the paging channel for paging block reception

1.5.3 Battery charger (LEON-G200 only)

For battery charging functionalities the module is provided with integrated circuitry and software. Two pins are available to connect the positive pole of the external DC supply used as charger.

Name	Description	Remarks
V_CHARGE	Charger Voltage Supply Input	V_CHARGE and CHARGE_SENSE pins must be externally connected.
CHARGE_SENSE	Charger Voltage Measurement Input	V_CHARGE and CHARGE_SENSE pins must be externally connected.

Table 4: Battery charger pins

The **V_CHARGE** pin is the charger supply input. The **CHARGE_SENSE** pin is connected to an internal ADC converter to measure the charging voltage.

☞ The **V_CHARGE** and **CHARGE_SENSE** pins must be externally connected together as shown in Figure 8.

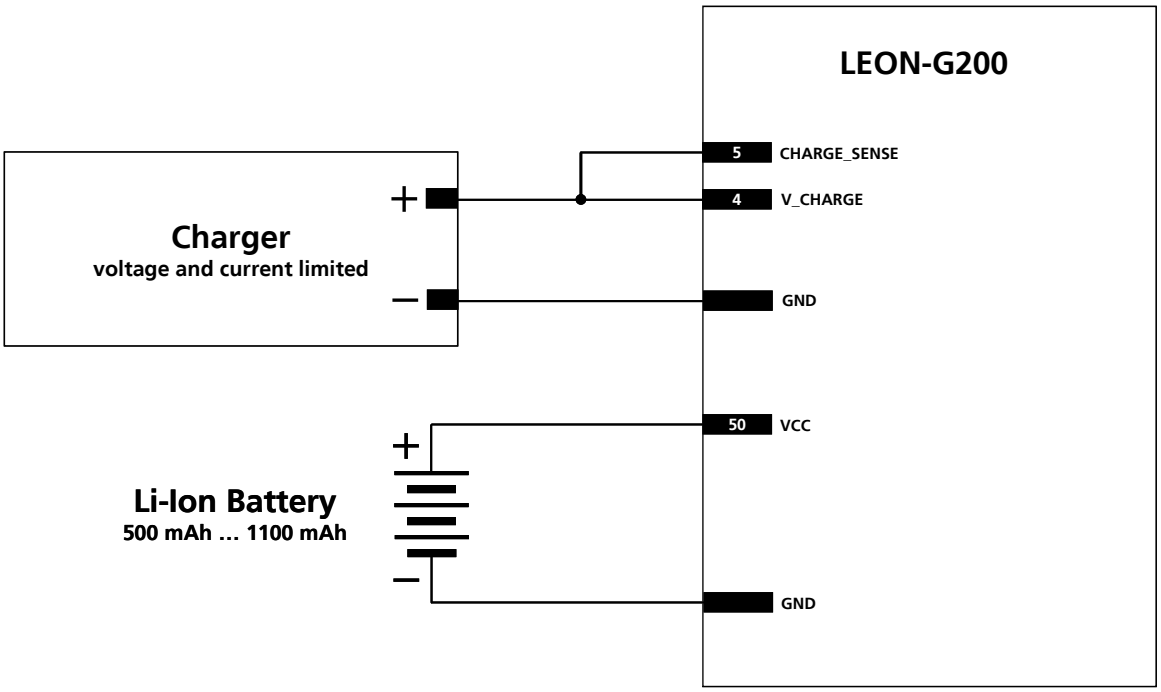

Figure 8: Connection of an external DC supply used as charger and a Li-Ion battery to the LEON-G200 module

When charger detection is implemented: a valid charger is recognized if the voltage provided to **V_CHARGE** and **CHARGE_SENSE** pins is within the operating range limits (5.6 V minimum, 15 V maximum). If the module is switched off, the charger circuitry generates the power on in charging mode after charger detection.

To prevent damage to the module and the battery, use only chargers that comply with the characteristics given in section 1.5.3.1.

The algorithm that controls battery charging, implements a classic Li-Ion battery charging process, divided into 4 phases:

1. Pre-Charge, at slow current for deeply discharged batteries
2. Fast Charge, at the maximum current provided by the external DC supply used as charger (must be current limited)
3. Top Charge, to complete the over-charging of the batteries, after the maximum voltage (4.2 V for Li-Ion battery) is reached
4. Trickle Charge, to maintain the battery at higher level of charge, if the external DC supply used as charger remains connected

If the batteries are deeply discharged (**VCC** voltage within 0 V and 3.1 V) and the device is in not-powered mode, the charger circuit starts pre-charging when a valid voltage is provided to the **V_CHARGE** and **CHARGE_SENSE** pins of the module. In the pre-charging phase, the charge transistor switch mounted inside the module is pulsed with 100 Hz and a duty cycle of 12.5%. This means the average charge current is reduced to avoid overheating of charger parts and to gently charge the deeply discharged batteries. Pre-charging is hardware controlled and continues as long as the **VCC** voltage reaches the 3.1 V typical limit, so the module is able to start the following charging phase.

During fast charging (following the pre-charging phase) the charge transistor switch mounted inside the module can be driven by software according to the charge algorithm. The duty cycle of the charge current never reaches 100%: the charge switch is not closed for 100% of the time but still pulsed with a 100 Hz clock with an on-time

of >99% of a period. The remaining off time is used to check if the AC-DC wall adapter is still connected since detection is critical when charging switch is closed.

The integrated charging circuit doesn't have any voltage or current limitation, therefore the charger must be chosen very carefully: during the fast charging phase, the battery is charged with the maximum DC current provided by the external DC supply used as charger, which must be current limited as described in the charger specification section.

When the battery voltage reaches the nominal maximum voltage (4.2 V for Li-Ion battery), charging enters the constant voltage phase (top charge algorithm): in this phase the average charging current decreases until the battery is completely charged.

After the constant voltage phase, the battery is maintained at a higher level of charge with the trickle charge algorithm until an external charger is connected to the module.

The charging process is enabled only within the temperature range: from 0°C to 50°C with a 5°C hysteresis to prevent rapid switching on and off as the temperature drifts around the set point: it is disabled when the temperature falls below 0°C and then enabled when it rises above 5°C; it is disabled when the temperature rises above 50°C and then enabled when falls below 45°C.

Battery over-voltage detection is implemented to switch-off charging if e.g. the battery is removed during charging. The over-voltage threshold level is set to the nominal value of 4.47 V (evaluated with 2% of tolerance).

1.5.3.1 Charger specification

☞ To avoid damage to the module, the external supply used as charging source must be voltage and current limited.

The value of the charger voltage limit must be lower or equal to 15 V. Since the module is not provided with an internal overvoltage protection circuit on the **V_CHARGE** and **CHARGE_SENSE** pins, the charging voltage must be lower or equal to the maximum acceptable charging voltage value of 15 V at any time: voltage spikes that may occur during connection or disconnection of the charger must be limited within this value.

The value of the charger current limit must be lower or equal to the value of the battery capacity plus 100 mA: the maximum acceptable value for the charger current limit depends on the capacity of the Li-Ion battery used. For example using a 500 mAh battery, the charger current limit must be lower or equal to 600 mA. Since the module is not provided with an internal over-current protection circuit on the **V_CHARGE** and **CHARGE_SENSE** pins, the charging current must be lower or equal to the maximum acceptable charging current value at any time: current spikes that may occur during charger connection or disconnection must be limited within this value.

☞ There may not be any capacitor on the charge path: a straight connection must be provided between the output of the external supply used as charging source and the **V_CHARGE** and **CHARGE_SENSE** pins of the module.

The charger must be able to provide a minimum open circuit output voltage greater or equal to 5.6 V for the valid charger detection.

A minimum current for the charger is not specified: this value has to be large enough to perform the whole battery charging process within the time interval specified by the application. For example using a 500 mAh battery, the minimum current available by the charger can be 400 mA to reach the complete charge of the battery within a useful period.

☞ DC supplies with fold-back current protection cannot be used as charger for the module.

Use a charger with the following electrical characteristics:

- 6 V DC voltage
- Current limit equal to the capacity of the used battery (i.e. 500 mA current limit if a 500 mAh battery is used)

The V-I output characteristics of the external supply used as charger must be within the valid area delineated by:

- the maximum acceptable charging voltage (equal to 15 V in any case)
- the minimum voltage valid for charger detection (equal to 5.6 V in any case)

- the maximum acceptable charging current (equal to the capacity value of the used battery plus 100 mA)
- the minimum charging current (specified by the application, e.g. 400 mA)

For example, Figure 10 and Figure 11 show the valid area for the charger V-I output characteristics using a 500 mAh Li-Ion battery (Figure 10) and a 1100 mAh Li-Ion battery (Figure 11).

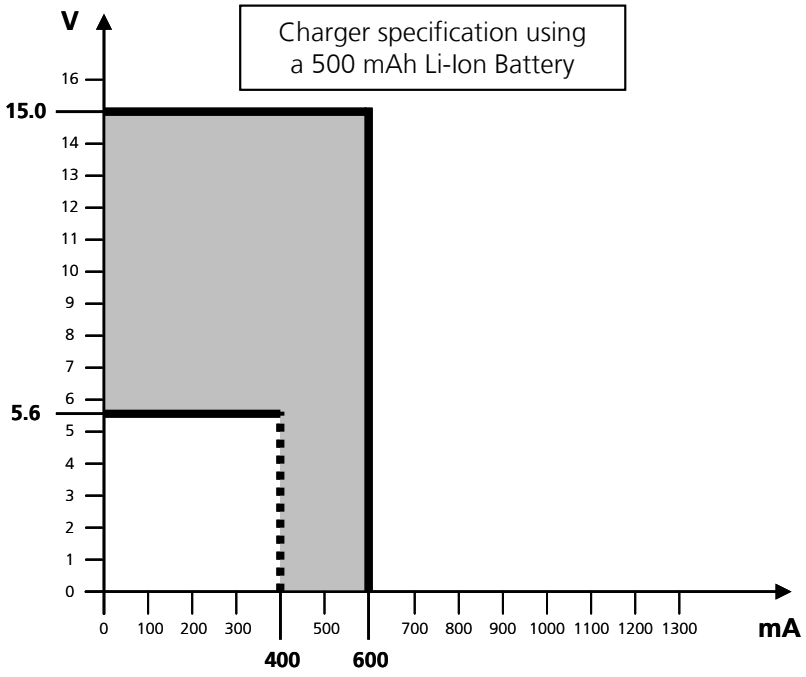

Figure 10: Valid area for the charger V-I output characteristics using a 500 mAh Li-Ion Battery

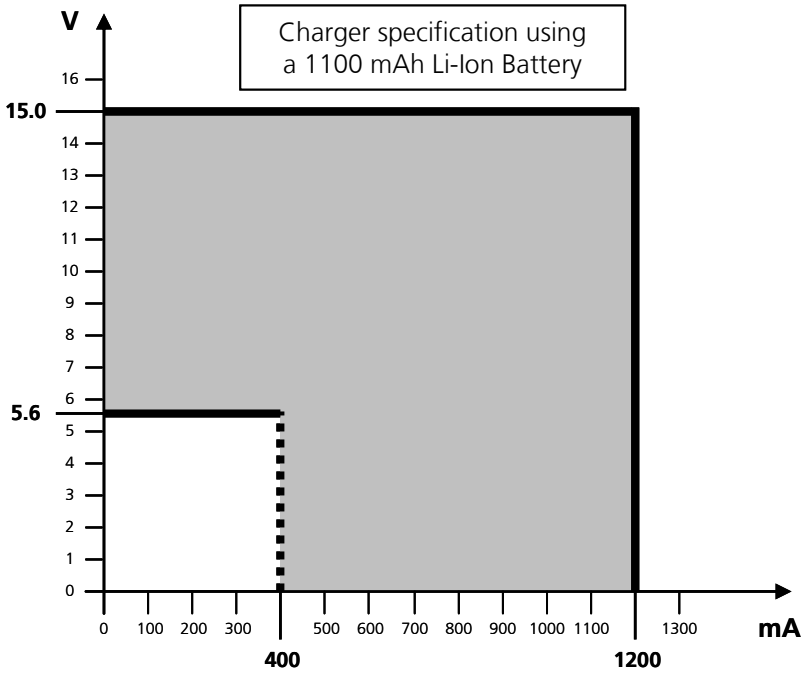

Figure 11: Valid area for the charger V-I output characteristics using a 1100 mAh Li-Ion Battery

1.5.4 Voltage Backup Power (V_BCKP)

The **V_BCKP** pin connects the Real Time Clock (RTC) supply, which is internally generated by a linear regulator integrated in the module chipset. The output of this linear regulator is enabled when the main voltage supply providing the module through VCC is within the valid operating range or if the module is switched-off.

The RTC provides the time reference (date and time) of the module, also in power-off mode, since the RTC runs when the **V_BCKP** voltage is within its valid range (specified in LEON-G100/G200 Data Sheet [1]). The RTC block is able to provide programmable alarm functions by means of the internal 32.768 kHz clock.

The RTC block has very low power consumption, but this is highly temperature dependent. For example at 25°C and a **V_BCKP** voltage of 2.0 V the power consumption is approximately 2 µA, whereas at 85°C and an equal voltage the power consumption increases to 5 µA.

The RTC can be supplied from an external back battery through the **V_BCKP**, when the main voltage supply is not provided to the module through **VCC**. This lets the time reference (date and time) run even when the main supply is not provided to the module. The module cannot switch on if a valid voltage is not present on **VCC** even when RTC is supplied through **V_BCKP** (meaning that **VCC** is mandatory to switch-on the module).

If **V_BCKP** is left unconnected and the main voltage supply of the module is removed from **VCC**, the RTC be supplied from the 1 µF buffer capacitor mounted inside the module. However, this capacitor is not able to provide a long buffering time: within 0.5 seconds the voltage on **V_BCKP** will go below the valid range (1 V min).

V_BCKP can be left unconnected if RTC is not required when **VCC** supply is removed.

If RTC is required to run for a time interval of T [seconds] at 25°C when **VCC** supply is removed, place a capacitor with a nominal capacitance of C [µF] at the **V_BCKP** pin. Chose the capacitor with the following formula:

C [µF] = (Current_Consumption [µA] x T [seconds]) / Voltage_Drop [V] = 2 x T [seconds]

The current consumption of the RTC is around 2 µA at 25°C, and the voltage drop is equal to 1 V (from the **V_BCKP** typical value of 2.0 V to the valid range minimum limit of 1.0 V).

For example, a 100 µF capacitor (such as the Murata GRM43SR60J107M) can be placed at the **V_BCKP** to provide a long buffering time. This capacitor will hold **V_BCKP** voltage within its valid range for around 50 seconds at 25°C, after the **VCC** supply is removed. If a very long buffering time is required, a 70 mF super-capacitor (e.g. Seiko Instruments XH414H-IV01E) can be placed at **V_BCKP**, with a 4.7 k series resistor to hold

the **V_BCKP** voltage within its valid range for around 10 hours at 25°C, after the **VCC** supply is removed. These capacitors will let the time reference run during a disconnection of the battery.

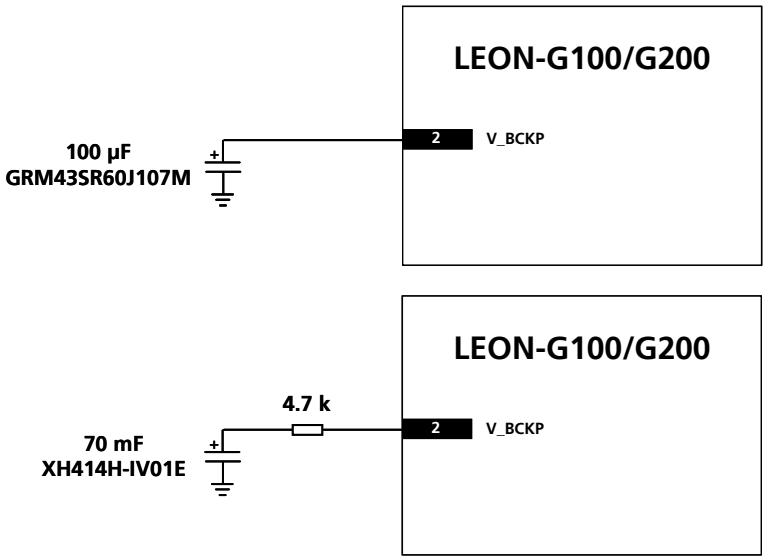

Figure 12: Real time clock supply (V_BCKP) application circuits using a 100 µF capacitor to let the RTC run for ~50 seconds at 25°C or using a 70 mF capacitor to let the RTC run for ~10 hours at 25°C when the VCC supply is removed

1.6 System functions

1.6.1 Module power on

The power-on sequence of the module is initiated in one of 4 ways:

- Rising edge on the **VCC** pin to a valid voltage as module supply
- Falling edge on the **PWR_ON** signal
- RTC alarm
- Rising edge on the **V_CHARGE** and **CHARGE_SENSE** to a valid voltage for charger detection (LEON-G200 only)

1.6.1.1 Rising edge on VCC

When a battery supply is connected to the **VCC** pin, the battery supervision circuit controls the subsequent activation of the power up state machines: the module is switched-on if the battery is connected for the first time and the voltage rises up to the valid limit of operation (See LEON-G100/G200 Data Sheet [1]).

1.6.1.2 Falling edge on the PWR_ON

Power-on sequence of the module starts when a falling edge occurs on the **PWR_ON** signal.

The electrical characteristics of the **PWR_ON** input pin are different from the other digital I/O interfaces: the high and the low logic levels have different operating ranges and the pin is tolerant against voltages up to the battery voltage. The detailed electrical characteristics are described in the datasheet.

☞ **PWR_ON** pin has high input impedance and is weakly pulled to the high level on the module. Avoid to keep it floating in noisy environment: to hold the high logic level stable, it is suggested to add a pull-up to the **V_BCKP** supply.

Force the **PWR_ON** input pin to the low level for at least 50 ms to cause a switch-on of the module, also if the power-on sequence is triggered by a falling edge on the **PWR_ON** signal.

If **PWR_ON** input is connected to an external device (e.g. application processor), use an open drain output of the external device with an external pull-up. Connect the pull-up to **V_BCKP** supply or to another supply rail present

on the application board, in range from 1.8 V to 3.3 V. It should also be available when the module is in power-off mode. Other possibility is to use a push-pull output of the external device, but take care to fix the proper level in all the possible scenarios to avoid an inappropriate switch-on of the module.

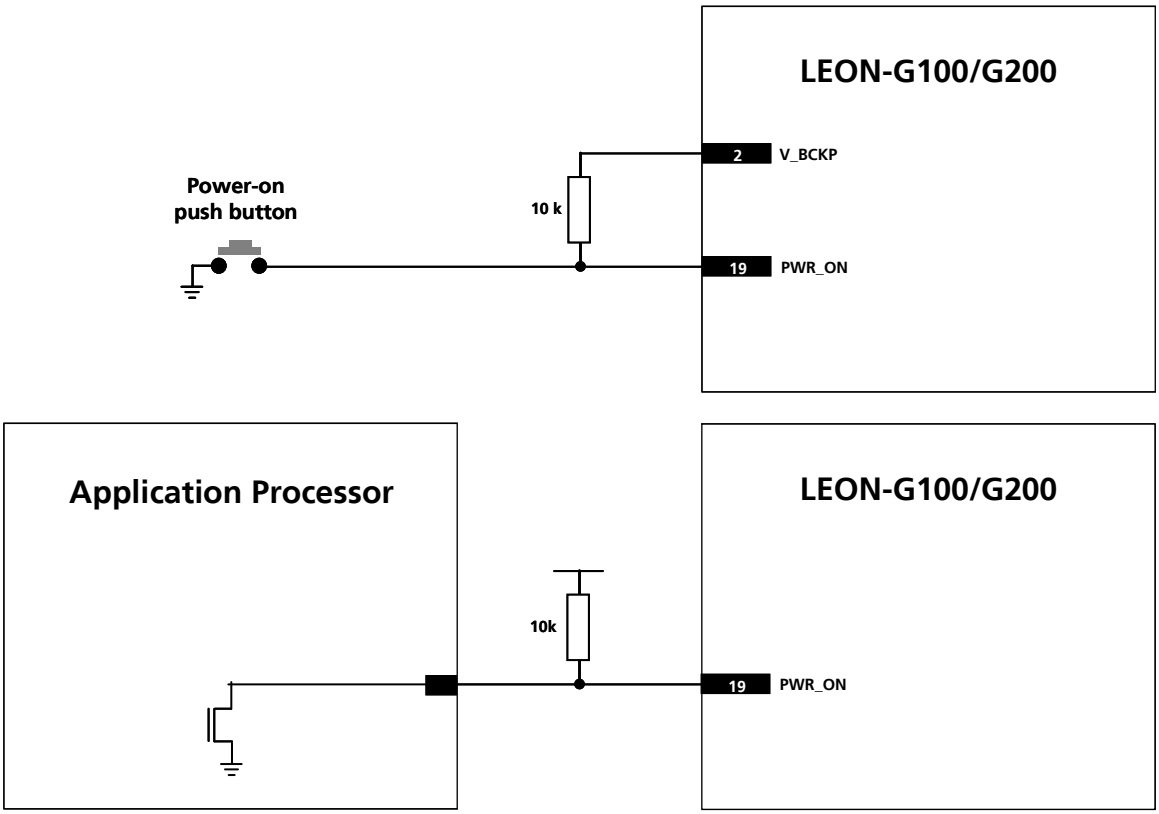

Figure 13: Power on (PWR_ON) application circuits using a push button or using an application processor

1.6.1.3 RTC alarm

The module can be switched-on by the RTC alarm if a valid voltage is applied to the VCC pin, when Real Time Clock system reaches a pre-defined scheduled time. The RTC system will then initiate the boot sequence by indicating to the power management unit to turn on power. Also included in this setup is an interrupt signal from the RTC block to indicate to the baseband processor, that a RTC event has occurred.

1.6.1.4 Rising edge on V_CHARGE and CHARGE_SENSE (LEON-G200 only)

The module can be switched-on by a charger: if the power management unit detects that a charger is connected to the module through the **V_CHARGE** and **CHARGE_SENSE** pins, it turns on power and the module is switched on in charge mode.

1.6.1.5 Additional considerations

If a valid battery voltage is connected to **VCC** before the detection of a start-up event, most input-output pads of the baseband chipset are locked in tri-state. The power down tri-state function isolates the outputs of the module from its environment, when no proper operation of the outputs can be guaranteed. To avoid an increase of the module current consumption in power down mode, any external signal of the digital interfaces connected to the module must be set low or tri-stated when the module is in not-powered mode or in the power-off mode.

After the detection of a start-up event, during the power-on sequence, the baseband core is held in reset state before enabling the input-output pads. Any signal of the module digital interfaces is held to the reset state until the application starts. See Figure 14. The reset state of all the module input-output pins is reported in the pin description table of the LEON-G100/G200 Data Sheet [1].

The power-on sequence is described in Figure 14.

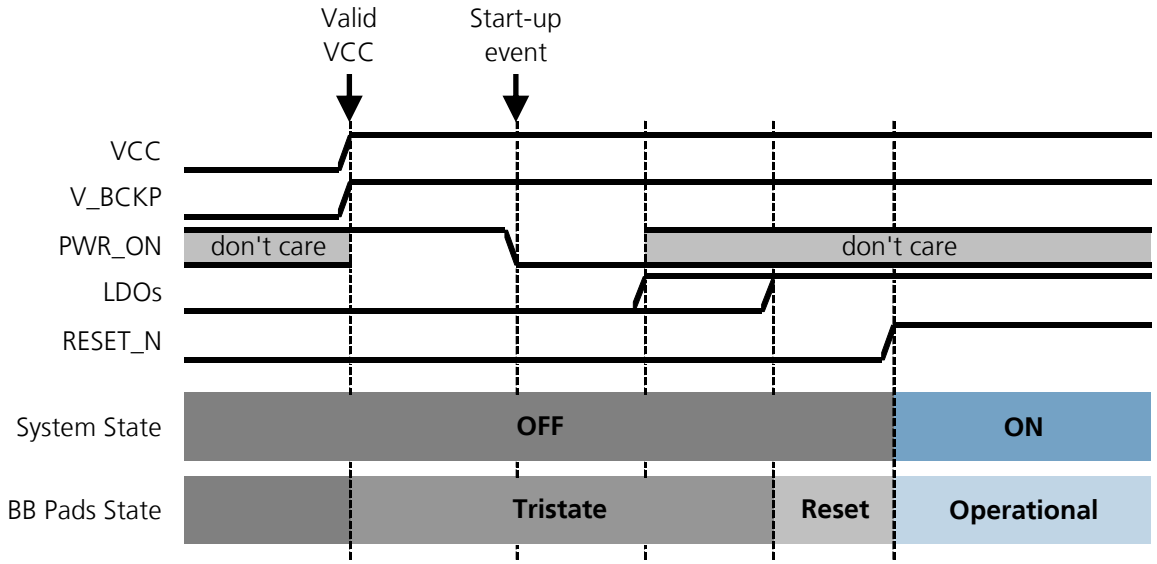

Figure 14: Power on sequence description

1.6.2 Module power off

LEON-G100/G200 can be switched-off by one of the following switch-off events:

- Via AT command AT+CPWROFF (more details in u-blox AT Commands Manual [2]). This is the only way to switch off the module.
- An under-voltage shutdown will be done if **VCC** falls below the valid operating limit.

After a switch-off event has been triggered, the digital pins are locked in tri-state by the module. All internal voltage regulators except the RTC supply are turned off in a defined power-off sequence.

☞ To avoid an increase of module current consumption in power-down mode, any external signal connected to the module digital pins (UART interface, Digital audio interface, HS_DET, GPIOs) must be set low or tri-stated when the module is in the not-powered or power-off modes. If the external signals connected to the module digital pins cannot be set low or tri-stated, insert a switch (e.g. Texas Instruments SN74CB3Q16244, or Texas Instruments TS5A3159, or Texas Instruments TS5A63157) between the two-circuit connections. Set the switch to high impedance when the module is in power-down mode (to avoid an increase of the module power consumption).

The power-off sequence is described in Figure 15.

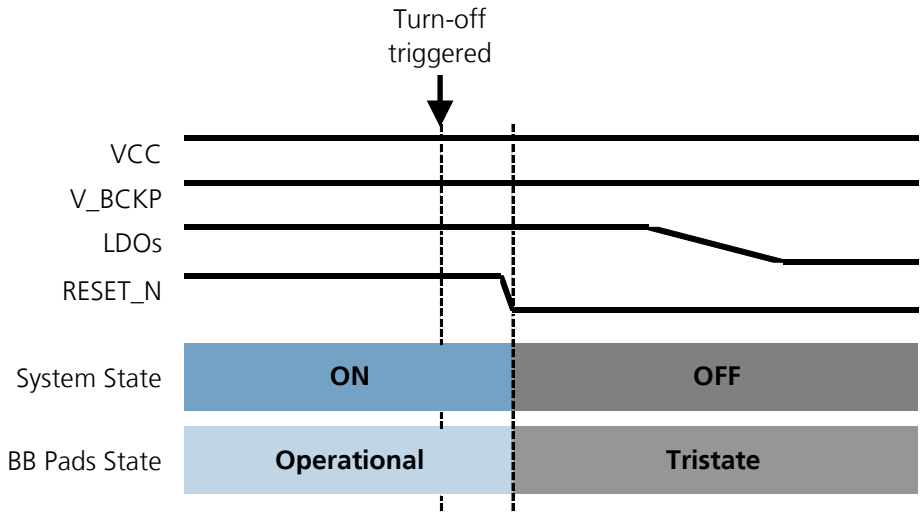

Figure 15: Power off sequence description

1.6.3 Module reset

Reset the module using **RESET_N**: this performs an external or hardware reset. When **RESET_N** pin is driven to low, the device is initialized into a defined reset state. An asynchronous reset of the entire module - except for the RTC - is triggered.

The electrical characteristics of **RESET_N** are different from the other digital I/O interfaces. The high and the low logic levels have different operating ranges and the pin is tolerant to voltages up to the battery voltage (a series protection diode is mounted inside the module to protect the pin). The detailed electrical characteristics are described in the LEON-G100/G200 Data Sheet [1].

RESET_N is pulled high by an integrated pull-up resistor, therefore an external pull-up is not required on the application board. An internal circuit pulls the level to 1.88 V (see Figure 16).

Force the **RESET_N** input pin to the low level for at least 50 ms to cause an external reset of the module. When the **RESET_N** is released from the low level, the module automatically starts its power-on reset sequence.

If **RESET_N** is connected to an external device (e.g. an application processor on an application board) an open drain output can be directly connected without any external pull-up. Otherwise, a push-pull output should be used. Make sure to fix the proper level on **RESET_N** in all possible scenarios, to avoid unwanted reset of the module.

The reset state of all input-output pins is reported in the pin description table in the LEON-G100/G200 Data Sheet [1].

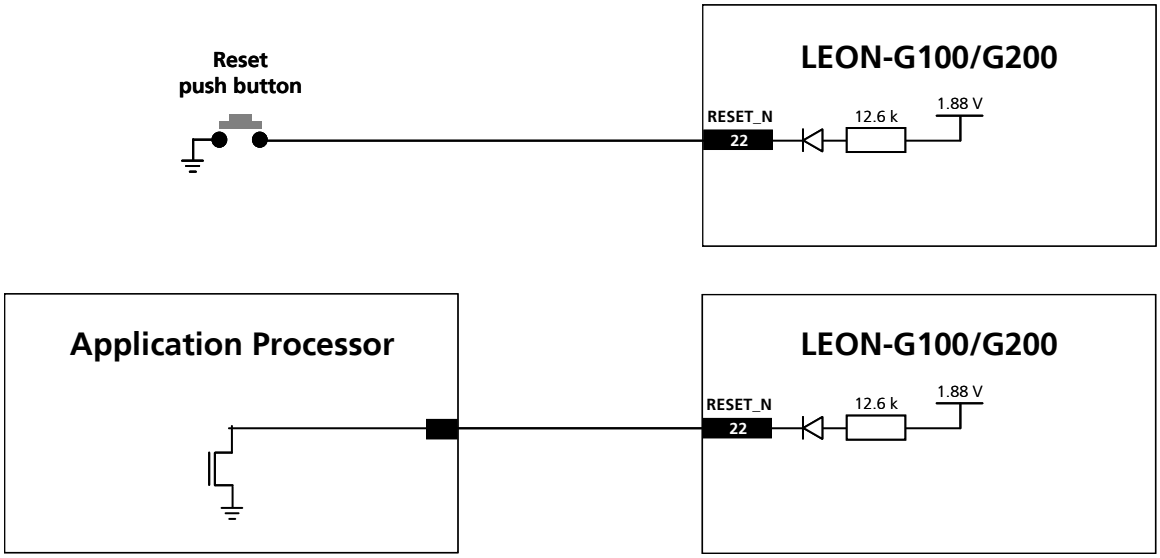

Figure 16: Application circuits to reset the module using a push button or using an application processor

When the module is in power-off mode or in reset state, **RESET_N** is pulled low (e.g. during boot sequence, a watchdog timer, or software reset).

RESET_N can indicate to an external application that the module is powered up and is not in the reset state, when:

- **RESET_N** connected through a biased inverting transistor to a LED
- **RESET_N** connected through a biased inverting and level shifting transistor to an input pin of an application processor that will sense a low logic level when the module is powered up and is not in the reset state;
- **RESET_N** connected through a pull-down resistor to an input pin of the application processor that senses a high logic level (1.8 V) when the module is powered up and is not in the reset state.

Examples of application circuits are shown in the Figure 17.

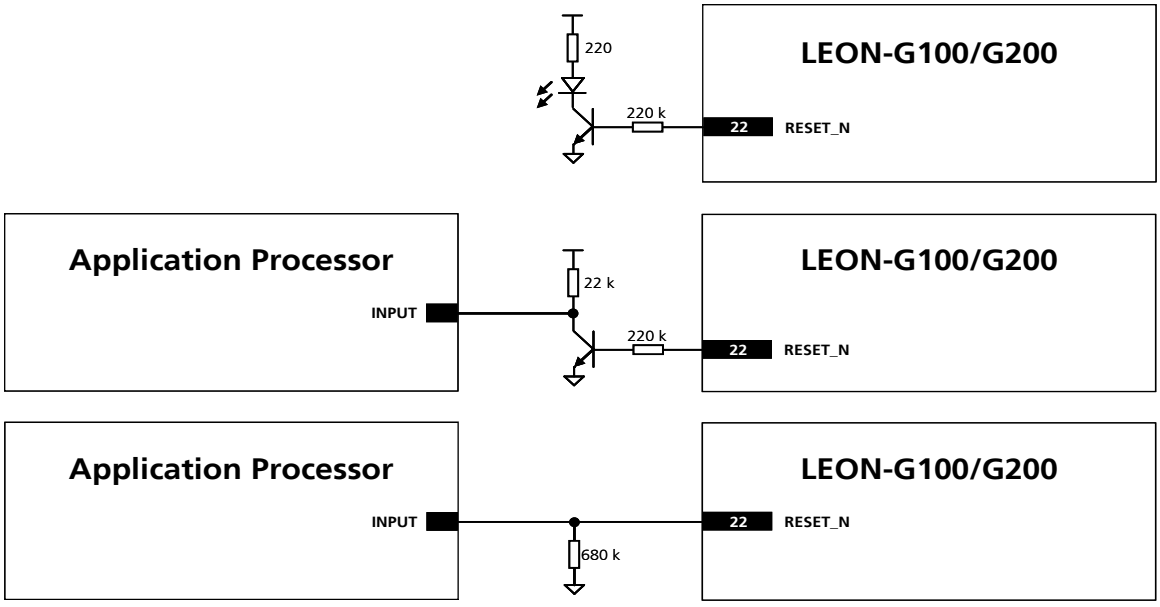

Figure 17: Application circuits to sense if the module is in the reset state

1.7 RF connection

The core of the RF part of the LEON-G100/G200 modules is the transceiver integrated in the GSM/GPRS single chip. The integrated receiver covers the four GSM bands GSM850 MHz, EGSM900 MHz, DCS1800 MHz and PCS1900 MHz, using two LNAs integrated in the RF Transceiver and providing quad-band operation. In the first duplexer the two low bands (RX path 850 MHz and 900 MHz) are separated, filtered, and routed to a single output and then connected to the LNA of the first low band receiver. In the same way the two high bands (RX paths 1800 MHz and 1900 MHz) are connected to the second duplexer to LNA of the second high band receiver.

Two different RF TX outputs are provided, one for 850/900 MHz bands and one for 1800/1900 MHz bands. The quad-band front end module amplifies these signals maintaining two separate paths.

By default the RF I/O signal is routed through a 50 Ω antenna interface.

The temperature dependent performance of the oscillator and RF high power circuits are controlled by the baseband with the aid of the NTC sensor.

1.8 Antenna supervisor

Antenna detection is internally performed by the module via **ANT**: the RF port is DC coupled to the ADC unit in the baseband chip. The module measures the DC voltage at **ANT**, in the range of 0..2 V. Additionally, the module can inject a known DC current (~ 100 µA) on **ANT** and measures the resulting DC voltage.

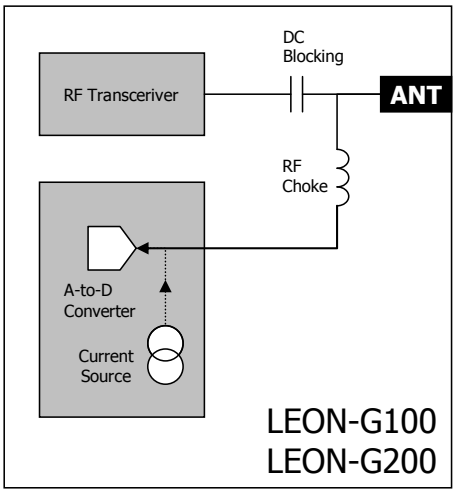

Figure 18: Antenna Supervisor internal circuit

If the DC voltage is present on **ANT**, or a DC connection to a known resistor at the radiating element is implemented, the module will be able to check the connection to the Antenna element.

Refer to the u-blox AT Commands Manual [2] for more details on how to access this feature.

1.9 Audio

LEON-G100/G200 modules provide four analog and one digital audio interfaces:

- Two microphone inputs:
  First microphone input: direct connection of an electret condenser microphone, used in the handset mode or in the hands free mode

Second microphone input: direct connection of an electret condenser microphone, used in the headset mode

- Two speaker outputs:
  First speaker output: a single ended low power audio output, can be used to directly connect a receiver (earpiece) used in handset mode or in headset mode

  Second speaker output: a differential high power audio output, can be used to directly connect a speaker or a loud speaker used in ring-tones or in hands-free mode
- Headset detection input
- I2S digital audio interface

1.9.1 Analog Audio interface

1.9.1.1 Uplink path (microphone inputs)

The TX (uplink) path of the analog audio front-end on the module consists of two identical microphone circuits. Two electret condenser microphones can be directly connected to the two available microphone inputs.

The main electrical specification requirements for the electret condenser microphone are 2.2 kΩ as maximum output impedance at 1 kHz and 2 V maximum standard operating voltage.

The following board-to-board pins are related to the uplink path (microphones inputs):

- **MIC_BIAS1:** single ended supply to the first microphone and represents the microphone signal input used in handset or hands free mode;
- **MIC_GND1:** local ground for the first microphone;
- **MIC_BIAS2:** single ended supply to the second microphone and represents microphone signal input used in headset mode;
- **MIC_GND2:** local ground for the second microphone.

For a description of the internal function blocks see Figure 24.

1.9.1.2 Downlink path (speaker outputs)

The RX (downlink) path of the analog audio front-end of the module consists of two speaker outputs available on the following pins:

- **HS_P:** low power single ended audio output available for handset or headset mode. This pin is internally connected to the output of the single ended audio amplifier of the chipset;
- **SPK_N/SPK_P:** high power differential audio output, available for hands free or ringer mode. These two pins are internally connected to the output of the high power differential audio amplifier of the chipset.

For a description of the internal function blocks see Figure 24.

Warning: excessive sound pressure from headphones can cause hearing loss.

Detailed electrical characteristics of the low power single-ended audio receive path and the high power differential audio receive path can be found in the LEON-G100/G200 Data Sheet [1].

Table 5 lists the signals related to analog audio functions.

Name	Description	Remarks
HS_P	Low power single-ended analog audio output	Used in handset or in headset mode
SPK_P	High power differential analog audio output	Used in ring tones or in hands free mode
SPK_N	High power differential analog audio output	Used in ring tones or in hands free mode
MIC_BIAS2	Second microphone analog bias	Single ended supply output and signal input for the second microphone. Used in headset mode
MIC_GND2	Second microphone analog reference	Local ground of second microphone
MIC_GND1	First microphone analog reference	Local ground of the first microphone
MIC_BIAS1	First microphone analog bias	Single ended supply output and signal input for first microphone. Used in handset or in hands free mode

Table 5: Analog Audio Signal Pins

☞ All audio lines on an Application Board must be routed in pairs, be embedded in GND (have the ground lines as close as possible to the audio lines), and maintain distance from noisy lines such as **VCC** and from components as switching regulators.

1.9.1.3 Handset mode

Handset mode is the default audio operating mode of LEON-G100/G200 modules:

- Handset microphone must be connected to inputs **MIC_BIAS1/MIC_GND1**
- Handset receiver must be connected to output **HS_P**.

Figure 19 shows an example of an application circuit connecting a handset (with a 2.2 kΩ electret microphone and a 32 Ω receiver) to the LEON-G100/G200 modules. Perform the following steps on the application circuit:

- Mount a series capacitor on the **HS_P** line to decouple the bias.
- Mount A 10 µF ceramic capacitor (e.g. Murata GRM188R60J106M) if connecting a 32 Ω receiver, or a load with greater impedance (such as a single ended analog input of a codec). Otherwise if a 16 Ω receiver is connected to the line, a ceramic capacitor with greater nominal capacitance must be used: a 22 µF series capacitor (e.g. Murata GRM21BR60J226M) is required.
- Mount a 33nH series inductor (e.g. Murata LQP15M33NG02) on each microphone line and a 27 pF bypass capacitor (e.g. Murata GRM1555C1H270J) on all audio lines to minimize RF coupling and TDMA noise.

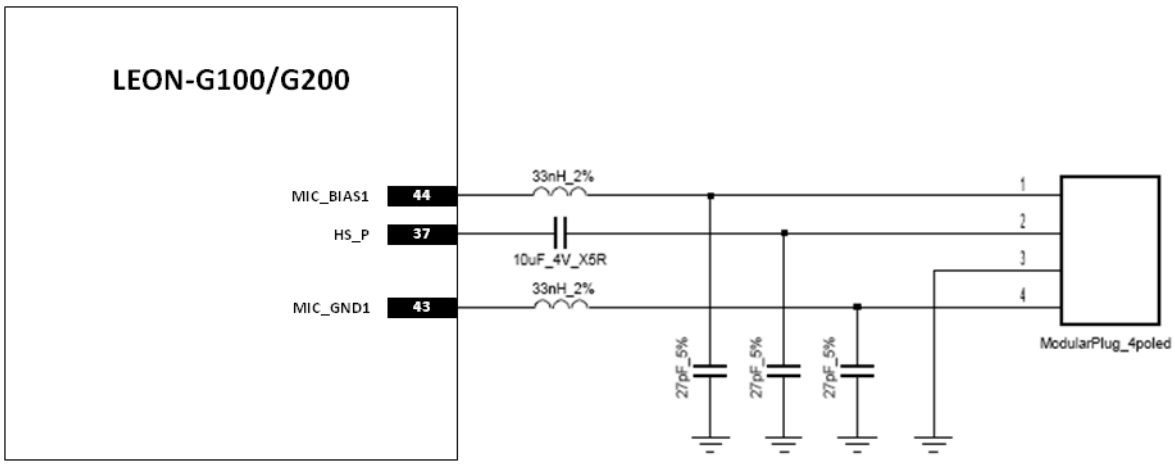

Figure 19: Handset connector application circuit

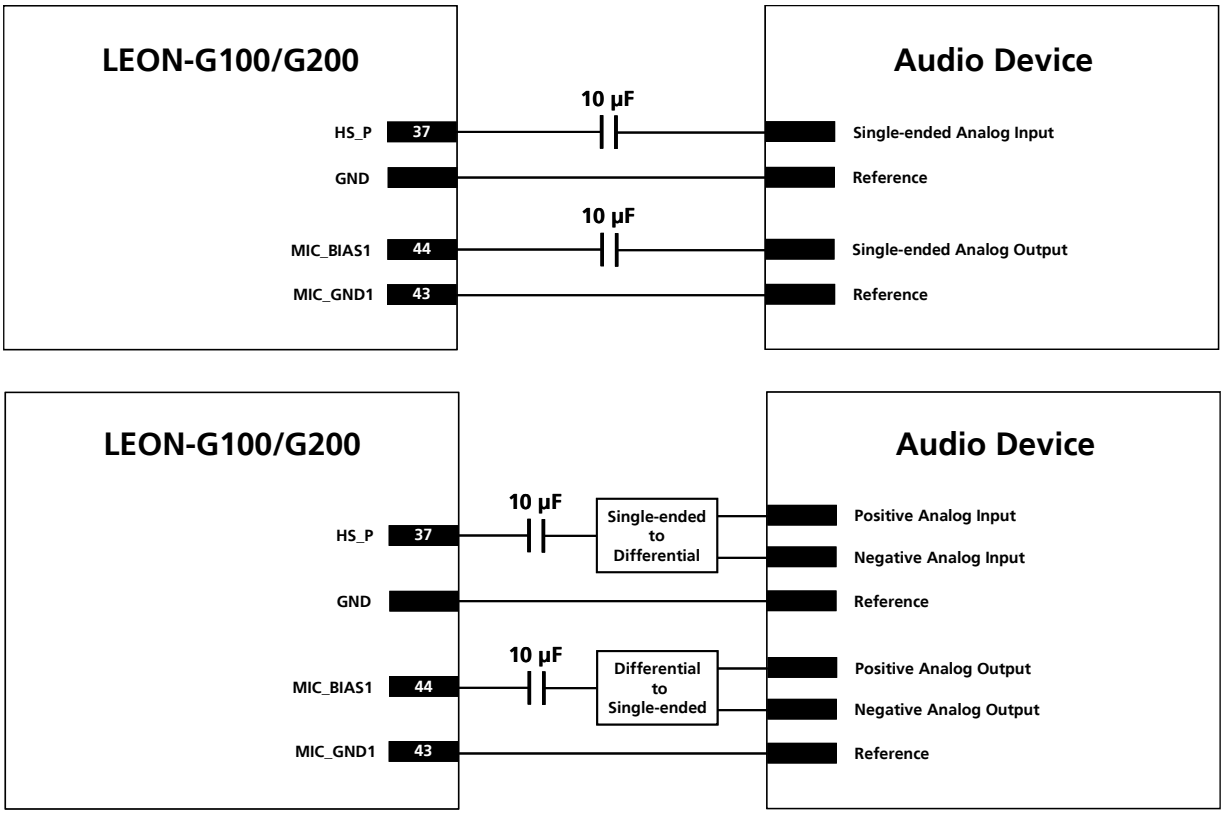

Figure 20: Application circuits to connect the LEON module to external audio devices with proper single-ended or differential analog audio inputs/outputs

1.9.1.4 Headset mode

The audio path is automatically switched from handset mode to headset mode when a rising edge is detected by the module on **HS_DET**. The audio path returns to the handset mode when the line returns to low level.

The audio path used in headset mode:

- Headset microphone must be connected to **MIC_BIAS2/MIC_GND2**
- Headset receiver must be connected to **HS_P**

Figure 21 shows an application circuit connecting a headset (with a 2.2 kΩ electret microphone and a 32 Ω receiver) to the LEON-G100/G200 modules. Pin 1 & 2 are shorted in the headset connector, causing **HS_DET** to be pulled low. When the headset plug is inserted **HS_DET** is pulled internally by the module, causing a rising edge for detection.

Perform the following steps on the application board (see Figure 21):

- Mount a series capacitor on the **HS_P** line to decouple the bias. 10 µF ceramic capacitor (e.g. Murata GRM188R60J106M) is required if a 32 Ω receiver or a load with greater impedance (as a single ended analog input of a codec) is connected to the line. When a 16 Ω receiver is connected to the line, a ceramic capacitor with greater nominal capacitance must be used: a 22 µF series capacitor (e.g. Murata GRM21BR60J226M) is required

- Mount a 33 nH series inductor (e.g. Murata LQP15M33NG02) on each microphone line, and a 27 pF bypass capacitor (e.g. Murata GRM1555C1H270J) on all audio lines to minimize RF coupling and the TDMA noise

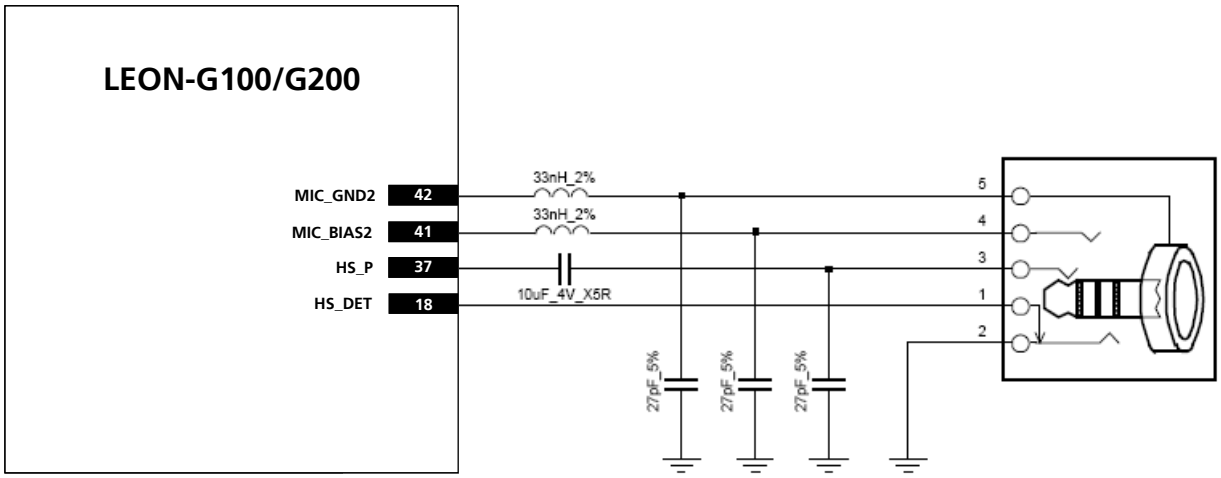

Figure 21: Headset connector application circuit

1.9.1.5 Hands-free mode

Hands-free functionality is implemented using appropriate DSP algorithms for voice band handling (echo cancellation and automatic gain control), managed via software. The viva voice operation provides the possibility to realize a phone call with a loudspeaker and a microphone. The audio path used in hands-free mode:

- Microphone is connected to the input pins **MIC_BIAS1/MIC_GND1**
- High power loudspeaker is connected to the output pins **SPK_P/SPK_N**.

When hands-free mode is enabled, the audio output signal on **HS_P** is disabled.

☞ The physical width of the high power audio outputs lines on the application board must be wide enough to minimize series resistance.

Figure 22 shows an application circuit for hands-free mode. In this example the LEON-G100/G200 module is connected to an 8 Ω speaker and a 2.2 kΩ electret microphone. Insert a 33 nH series inductor (e.g. Murata LQP15M33NG02) on each microphone line and a 27 pF bypass capacitor (e.g. Murata GRM1555C1H270J) on all audio lines to minimize RF coupling and the TDMA noise.

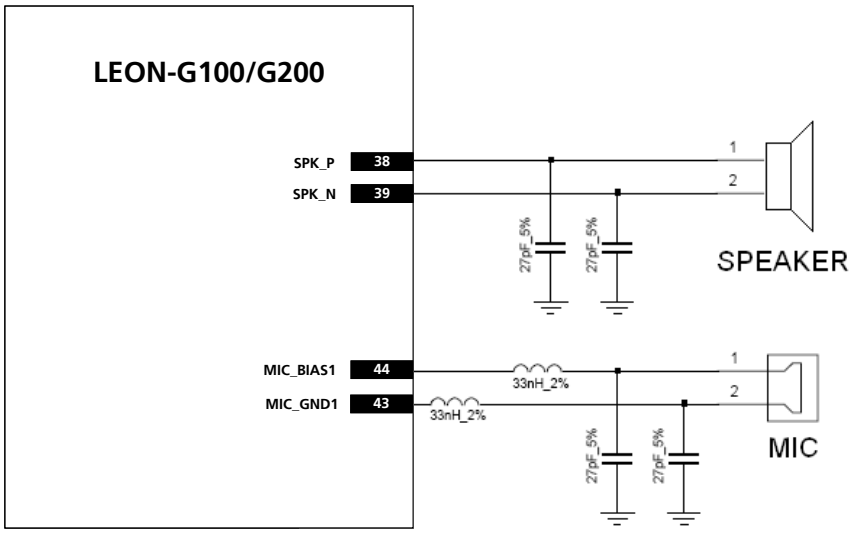

Figure 22: Hands free mode application circuit

1.9.1.6 Connection to an external analog audio device

When the LEON-G100/G200 module analog audio output is connected to an external audio device, **HS_P** analog audio output can be used. A 10 µF series capacitor (e.g. Murata GRM188R60J106M) must be inserted between the **HS_P** output and the single ended analog input of the external audio device (to decouple the bias). An additional single-ended to differential circuit is required for audio devices with a differential analog input. The signal levels can be adapted by setting gain using AT commands, but additional circuitry must be inserted if the **HS_P** output level of the module is too high for the input of the audio device.

If LEON-G100/G200 module analog audio input is connected to an external audio device, **MIC_BIAS1/MIC_GND1** can be used (default analog audio input of the module). Insert a 10 µF series capacitor (e.g. Murata GRM188R60J106M) between the single ended analog output of the external audio device and **MIC_BIAS1**. Connect the reference of the single ended analog output of the external audio device to **MIC_GND1**. If the external audio device is provided with a differential analog output, insert an additional differential to single ended circuit. The signal levels can be adapted by setting gain using AT commands, but additional circuitry must be inserted if the output level of the audio device is too high for **MIC_BIAS1**.

Examples of connecting the LEON-G100/G200 modules to external audio applications are shown in Figure 23.

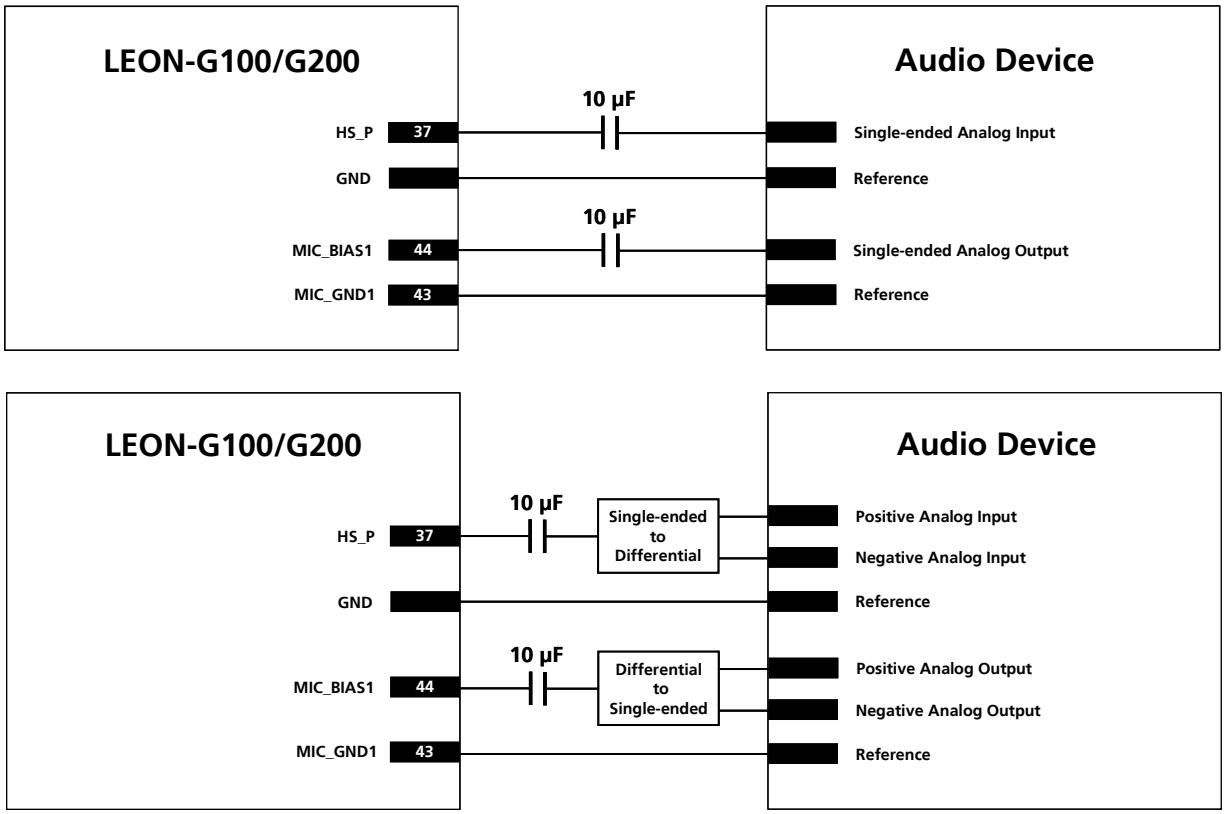

Figure 23: Application circuits to connect the LEON module to external audio devices with appropriate single-ended or differential analog audio inputs/outputs

1.9.2 Digital Audio interface (LEON-G200 only)

LEON-G200 supports a bidirectional 4-wire I2S digital audio interface. The module acts as master only. The I2S pins are listed in Table 6:

Name	Description	Remarks
I2S_WA	I2S word alignment	Module output (master)
I2S_TXD	I2S transmit data	Module output
I2S_CLK	I2S clock	Module output (master)
I2S_RXD	I2S receive data	Module input

Table 6: I2S interface pins

The I2S interface can be can be used in two modes:

- PCM mode: I2Sx
- Normal I2S mode: I2Sy

Beyond the supported transmission modality, the main difference between the PCM mode and the normal I2S mode is represented by the logical connection to the digital audio processing system integrated in the chipset firmware (see Figure 24):

- In PCM mode provides complete audio processing functionality
- Normal I2S mode: digital filters, digital gains, side tone, some audio resources as tone generator, info tones (e.g. free tone, connection tone, low battery alarm), and ringer are not available

The I2S interface is activated and configured using AT commands, see the u-blox AT commands manual [2].

If the I2S interface is used in PCM mode, digital path parameters can be configured and saved as the normal analog paths, using appropriate path index as described in the u-blox AT commands manual [2]. Analog gain parameters of microphone and speakers are unused when digital path is selected.

☞ Any external signal connected to the digital audio interface must be set low or tri-stated when the module is in power down mode to avoid an increase of module power consumption. If the external signals connected to the digital audio interface cannot be set low or tri-stated, insert a multi channel digital switch (e.g. Texas Instruments SN74CB3Q16244, TS5A3159, or TS5A63157) between the two-circuit connections and set to high impedance when the module is in power down mode.

☞ For debug purposes, include a test point at each I2S pin also if the digital audio interface is not used.

1.9.2.1 PCM mode

In PCM mode **I2S_TX** and **I2S_RX** are respectively parallel to the analog front end **I2S_RX** and **I2S_TX** as internal connections to the voice processing system (see Figure 24), so resources available for analog path can be shared:

- Digital filters and digital gains are available in both uplink and downlink direction. Configure using AT commands
- Ringer tone and service tone are mixed on the TX path when active (downlink)
- The HF algorithm acts on I2S path

Main features of the I2S interface in PCM mode:

- I2S runs in PCM - short alignment mode (configurable with AT commands)
- Module functions as I2S master (**I2S_CLK** and **I2S_WA** signals generated by the module)
- **I2S_WA** signal always runs at 8 kHz
- **I2S_WA** toggles high for 1 or 2 CLK cycles of synchronism (configurable), then toggles low for 16 CLK cycles of sample width. Frame length can be 1 + 16 = 17 bits or 2 + 16 = 18 bits
- **I2S_CLK** frequency depends on frame length. Can be 17 x 8 kHz = 136 kHz or 18 x 8 kHz = 144 kHz
- **I2S_TX**, **I2S_RX** data are 16 bit words with 8 kHz sampling rate, mono. Data are in 2's complement notation. MSB is transmitted first
- When **I2S_WA** toggles high, first synchronism bit is always low. Second synchronism bit (present only in case of 2 bit long **I2S_WA** configuration) is MSB of the transmitted word (MSB is transmitted twice in this case)
- **I2S_TX** changes on **I2S_CLK** rising edge, **I2S_RX** changes on **I2S_CLK** falling edge

1.9.2.2 Normal I2S mode

Normal I2S supports:

- 16 bits word
- mono interface
- 8 kHz frequency

Main features of I2S interface in Normal I2S mode:

- **I2S_WA** signal always runs at 8 KHz and the channel can be either high or low;
- **I2S_TX** data 16 bit words with 32 bit frame and 2, dual mono (the word can be written on 2 channels). Data are in 2's complement notation. MSB is transmitted first. The MSB is first transmitted; the bits change on **I2S_CLK** rising or falling edge (configurable);
- **I2S_RX** data are read on the **I2S_CLK** edge opposite to **I2S_TX** writing edge;
- **I2S_CLK** frequency depends by the number of bits and number of channels so is 16 x 2 x 8 KHz = 256 KHz.

The modes are configurable through a specific AT command (refer to u-blox AT commands manual [2]) and the following parameters can be set:

- **I2S_TX** word can be written while **I2S_WA** is high, low or both;
- MSB can be 1 bit delayed or non-delayed on **I2S_WA** edge;
- **I2S_TX** data can change on rising or falling edge of **I2S_CLK** signal (Rising edge in this example);
- **I2S_RX** data read on the opposite front of **I2S_CLK** signal.

1.9.3 Voiceband processing system

Digital voiceband processing on the LEON-G100/G200 is implemented in the DSP core inside the baseband chipset. The analog audio front-end of the chipset is connected to the digital system through 16 bit ADC converters in the uplink path, and through 16 bit DAC converters in the downlink path. The digitized TX and RX voiceband signals are both processed by digital gain stages and decimation filter in TX, interpolation filters in RX path. The processed digital signals of TX and RX are connected to the TEAKLite DSP for various tasks (i.e. speech codec, digital mixing and sidetone, audio filtering) implemented in the firmware modules.

External digital audio devices can be interfaced to the DSP voiceband processing system via the I2S interface.

The voiceband processing system can be split up into three different parts:

- Sample-based Voiceband Processing (at 8 kHz / 125 µs)
- Frame-based Voiceband Processing (20 ms)
- Circular Mixing Buffer, to mix different sound signals (Sound Ringer, MIDI synthesizer) with the downlink signal at 48 kHz

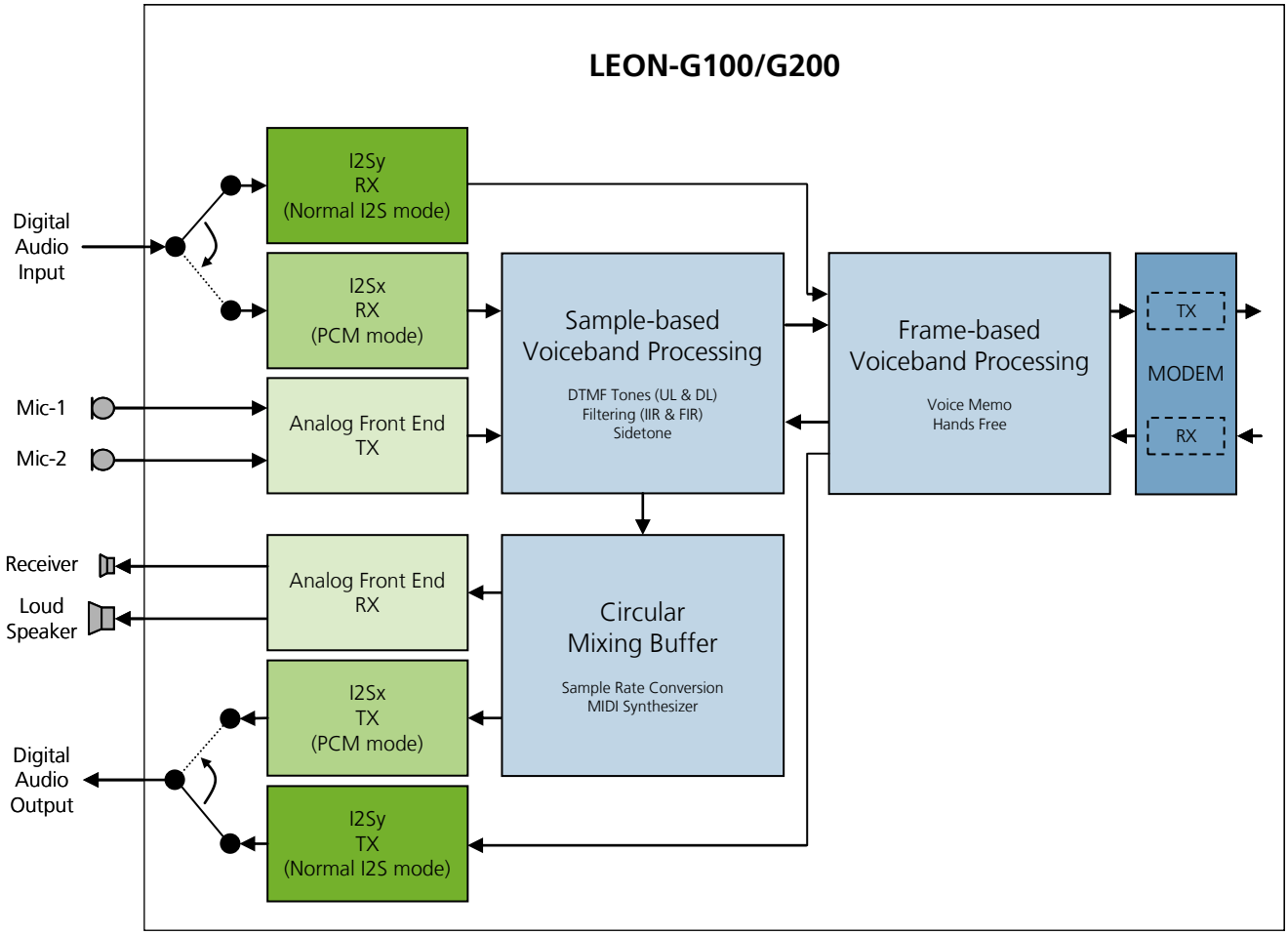

Figure 24: LEON-G100/G200 voiceband processing system block diagram

The sample-based voiceband processing is done on an interrupt level and its main task is to transfer the voiceband samples from either analog audio front-end TX path or I2Sx RX path to the Voiceband Sample Buffer and from the Voiceband Sample Buffer to the analog audio front-end RX path and/or I2Sx TX path.

First the TX path (uplink) is processed: the input sample is scaled, filtered and before it is copied into the voiceband input buffer for the speech frame based processing and it is used to generate the sidetone for the RX path processing. Furthermore the signal is mixed with the output of the circular buffer.

The frame-based voiceband processing consists of these operating parts: voice memo; echo cancellation and auto gain control for hands free mode. The uplink path starts with output samples from voiceband buffer and stops with speech encoding. The downlink path starts with output samples from speech decoder and stops with output samples to voiceband buffer.

The circular buffer is a 3000 word buffer to store and mix the voiceband samples from external sources (synthesizer data). The buffer has a circular structure, so that when the write pointer reaches the end of the buffer, it is wrapped to the begin address of the buffer.

Two different sample-based sample rate converters are used: an interpolator, required to convert the sample-based voiceband processing sampling rate of 8 kHz to the analog audio front-end output rate of 47.6 kHz; a decimator, required to convert the circular buffer sampling rate of 47.6 kHz to the I2Sx TX or the uplink path sample rate of 8 kHz.

1.9.3.1 Audio codecs

The following speech codecs are supported by firmware on the DSP:

- GSM Half Rate (TCH/HS)
- GSM Full Rate (TCH/FS)
- GSM Enhanced Full Rate (TCH/EFR)
- 3GPP Adaptive Multi Rate (AMR) (TCH/AFS+TCH/AHS)

1.9.3.2 Echo cancelation and noise reduction

LEON-G100/G200 support algorithms for echo cancellation, noise suppression and automatic gain control. Algorithms are configurable with AT commands (refer to the u-blox AT Commands Manual [2]).

1.9.3.3 Digital filters and gains

Audio parameters such as digital filters, digital gain, Side-tone gain (feedback from uplink to downlink path) and analog gain are available for uplink and downlink audio paths. These parameters can be modified by dedicated AT commands and be saved in 2 customer profiles in the non-volatile memory of the module (refer to the u-blox AT Commands Manual [2]).

1.9.3.4 Ringer mode

LEON-G100/G200 modules support polyphonic ring tones. The ringer tones are generated by a built-in generator on the chipset and then amplified by the internal amplifier.

The synthesizer output is only mono and cannot be mixed with TCH voice path (the two are mutually exclusive). To perform in-band alerting during TCH with voice path open, only Tone Generator can be used.

Polyphonic standard format supported.

1.10 SIM interface

An SIM card interface is provided on the board-to-board pins of the module: the high-speed SIM/ME interface is implemented as well as automatic detection of the required SIM supporting voltage.

Both 1.8 V and 3 V SIM types are supported: activation and deactivation with automatic voltage switch from 1.8 to 3 V is implemented, according to ISO-IEC 78-16-e specifications. The SIM driver supports the PPS (Protocol and Parameter Selection) procedure for baud-rate selection, according to the values determined by the SIM Card.

Table 7 describes the board to board pins related to the SIM interface:

Name	Description	Remarks
VSIM	SIM supply	1.80 V typical or 2.85 V typical automatically generated by the module
SIM_CLK	SIM clock	3.25 MHz clock frequency
SIM_IO	SIM data	
SIM_RST	SIM reset	

Table 7: SIM Interface pins

Figure 25 shows the circuit with the minimal connections between the LEON module and the SIM card.

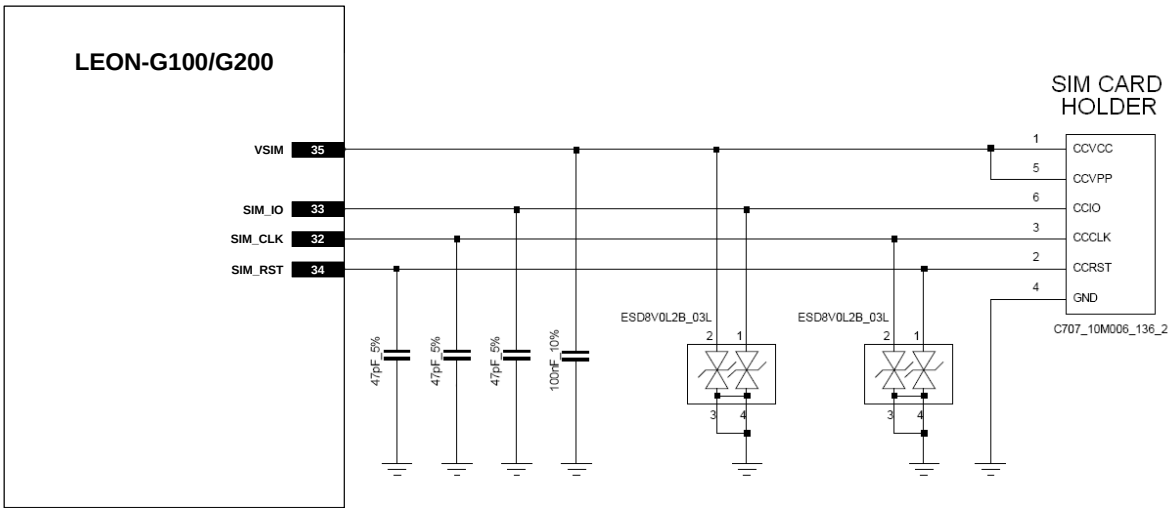

Figure 25: SIM interface application circuit

When connecting the module to SIM connector perform the following steps on the application board:

- To prevent RF coupling: ground via a 47 pF capacitor (e.g. Murata GRM1555C1H470J) near the SIM connector on each SIM signal (**SIM_CLK**, **SIM_IO**, **SIM_RST**)
- Ground via a 100 nF capacitor (e.g. Murata GRM155R71C104K) on the SIM supply (**VSIM**).
- Mount very low capacitance ESD protection (e.g. Infineon ESD8V0L2B-03L or AVX USB0002RP) near the SIM card connector
- Limit capacitance on each SIM signal to match the SIM specifications: the connections should always be routed as short as possible

1.10.1 SIM functionality

The following SIM services are supported:

- Abbreviated Dialing Numbers (ADN)
- Fixed Dialing Numbers (FDN)
- Last Dialed Numbers (LDN)
- Service Dialing Numbers (SDN)

SIM Toolkit R99 is supported.

1.11 Serial Communication

1.11.1 Asynchronous serial interface (UART)

The UART interface is an 8-wire unbalanced asynchronous serial interface provided for all communications with LEON-G100/G200 modules: AT commands interface, GPRS data and CSD data, software upgrades.

The UART interface provides RS-232 functionality conforming to the ITU-T V.24 Recommendation (more details available in [3]), with CMOS compatible signal levels: 0 V for low data bit or ON state, and 2.85 V for high data bit or OFF state. An external voltage translator (Maxim MAX3237) is required to provide RS-232 compatible signal levels. For the detailed electrical characteristics refer to the LEON-G100/G200 Data Sheet [1].

LEON-G100/G200 modules are designed to operate as a GSM/GPRS modem, which represents the data circuit-terminating equipment (DCE) as described by the ITU-T V.24 Recommendation. A customer application processor connected to the module through the UART interface represents the data terminal equipment (DTE).

☞ The signal names of the LEON-G100/G200 UART interface conform to ITU-T V.24 Recommendation.

The UART interface includes data lines, hardware flow control lines, modem status and control lines:

- **RxD**: module data output, provides the functionality of the ITU-T V.24 Circuit 104 (Received data)
- **TxD**: module data input, provides the functionality of the ITU-T V.24 Circuit 103 (Transmitted data)
- **CTS**: module hardware flow control output, provides the functionality of the ITU-T V.24 Circuit 106 (Ready for sending)
- **RTS**: module hardware flow control input, provides the functionality of the ITU-T V.24 Circuit 105 (Request to send)
- **DTR**: module input, provides the functionality of the ITU-T V.24 Circuit 108/2 (Data terminal ready)
- **DSR**: module output, provides the functionality of the ITU-T V.24 Circuit 107 (Data set ready)
- **DCD**: module output, provides the functionality of the ITU-T V.24 Circuit 109 (Data channel received line signal detector)
- **RI**: module output, provides the functionality of the ITU-T V.24 Circuit 125 (Calling indicator)

1.11.1.1 UART features

The AT commands that are supported on the module through the UART interface are:

- AT commands according to [7].
- AT commands according to [8].
- AT commands according to [9].
- u-blox AT commands.

All flow control handshakes are supported by the UART interface and can be set by appropriate AT commands (see u-blox AT Commands Manual [2]): hardware flow control (RTS/CTS), software flow control(XON/XOFF), or none flow control.

Autobauding is supported and can be enabled or disabled by an AT command (see u-blox AT Commands Manual [2]). Autobauding is enabled by default.

☞ Hardware flow control is default.

☞ For the complete list of supported AT commands and their syntax refer to the u-blox AT Commands Manual [2].

☞ Autobauding result can be unpredictable with spurious data if idle-mode (power-saving) is entered and the hardware flow control is disabled.

The following baud rates can be configured using AT commands:

- 4800 bps,
- 9600 bps,
- 19200 bps,
- 38400 bps,
- 57600 bps,
- 115200 bps. Default when autobauding disabled.

The following baud-rates are available with autobauding only:

- 1200 bps,
- 230400 bps.

Automatic frame recognition is supported: this feature is enabled in conjunction with autobauding only, which is enabled by default. The frame format can be:

- 8N1 (8 data bits, No parity, 1 stop bit),
- 8E1 (8 data bits, even parity, 1 stop bit),
- 8O1 (8 data bits, odd parity, 1 stop bit),
- 8N2 (8 data bits, No parity, 2 stop bits).

The default frame configuration with fixed baud rate is 8N1, described in the Figure 26.

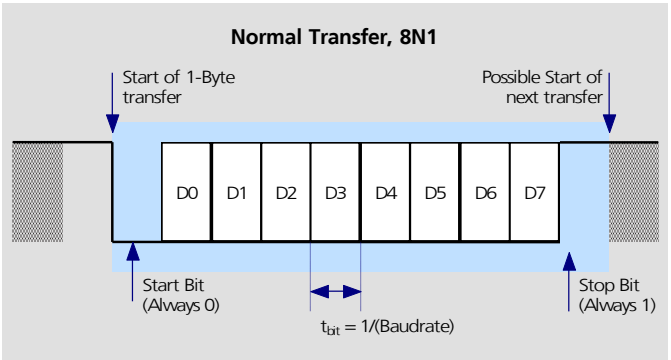

Figure 26: UART default frame format (8N1) description

1.11.1.2 UART signal behavior

See Table 2 for a description of operating modes and states referred to in this section.

By default the **RxD** and the **TxD** lines are set to the OFF state at UART initialization, following the boot sequence when the module is switched on. The module holds **RxD** and **TxD** in the OFF state until data is either transmitted or received by the module: an active pull-up is enabled inside the module on the **TxD** input.

The hardware flow control output (**CTS** line) indicates when the module is in active mode and the UART interface is enabled: the module drives the **CTS** line to the ON state or to the OFF state when it is either prepared or not prepared to accept data from the external device (DTE).

After the boot sequence the **CTS** line is set to the ON state at UART initialization, when the module is in active-mode and ready to operate. By default the module automatically enters idle-mode (power saving) unless this mode has been disabled using an AT command (see u-blox AT Commands Manual [2]).Thus data delivered by the DTE can be lost if no hardware flow-control is enabled. The module periodically wakes up from idle-mode to the active-mode to be synchronized with network activity. Idle-mode time is fixed by network parameters and can be up to ~2.1 s. When the module wakes up to active-mode, the UART interface is enabled: the **CTS** line is switched to the ON state and is held in this state for a minimum of ~11 ms.

The behavior of hardware flow-control output (**CTS** line) during the module normal operations (idle mode and active mode) is illustrated in Figure 27.

The time delay for the module to go from active-mode to idle-mode is variable and depends (in addition to dependency on network parameters) on the timeout from the last data received at the serial port. This timeout is configurable by the AT+UPSV command, between 40 GSM frames (~184 ms) and 65000 GSM frames (~300 s) Default value is 2000 GSM frames (~9.2 s).

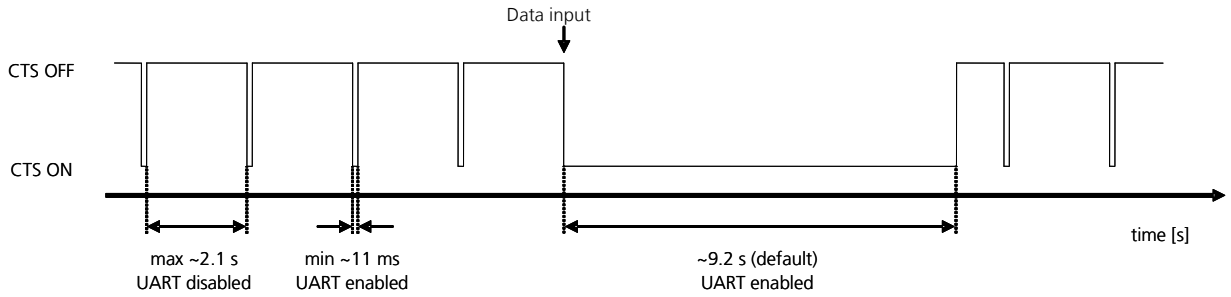

Figure 27: CTS behavior during normal module operation: the CTS line indicates when the module is able (CTS = ON) or not able (CTS = OFF) to accept data from the DTE and communicate through the UART interface

The hardware flow control input (**RTS** line) is set by default to OFF state at UART initialization at the end of the boot sequence, after the module switch on. **RTS** line is then held by the module in the OFF state if hardware flow- control is not enabled by the DTE: an active pull-up is enabled inside the module on the **RTS** input.

The module drives the **DSR** line to indicate whether it is ready to operate or not. After the module switches on, the **DSR** line switches from ON state to OFF state as shown in Figure 28. During the Boot process of the module, **DSR** is forced to OFF, until the module is not ready to operate. It is switched to ON state when the module is ready to operate. The time T_{switch} depends on the duration of the boot process, and is in the range of ~1 s.

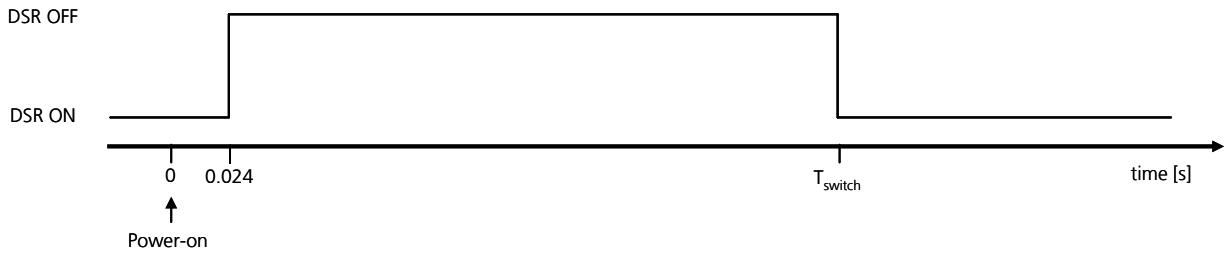

Figure 28: DSR behavior at power-on

The **DTR** line is set by default to the OFF state at the UART initialization, at the end of the boot sequence after the module switch on. The DTR line is then held by the module in the OFF state if the line is not activated by the DTE: an active pull-up is enabled inside the module on the **DTR** input.

By default the **RI** and the **DCD** lines are set to the OFF state at UART initialization, at the end of the boot sequence. The **RI** line is then held by the module in the OFF state until an incoming call or SMS is received. The **DCD** line is held in the OFF state until a data call is accepted.

During an incoming call the **RI** line is switched from the OFF state to the ON state with a 4:1 duty cycle and a 5 second period (ON for 1 second, OFF for 4 second, see Figure 29), until the DTE attached to the module sends the ATA string and the module accepts the incoming data call. The RING string sent by the module (DCE) to the serial port at constant time intervals is not correlated with the switch of the **RI** line to the ON state. When the data call is accepted, the module is set to ON state and the serial line **DCD** sends the CONNECT<communication baudrate> to the DTE. DTE sends data through the DCE and the GSM network to the remote DCE-DTE system and data communication can be performed as for outgoing data calls.

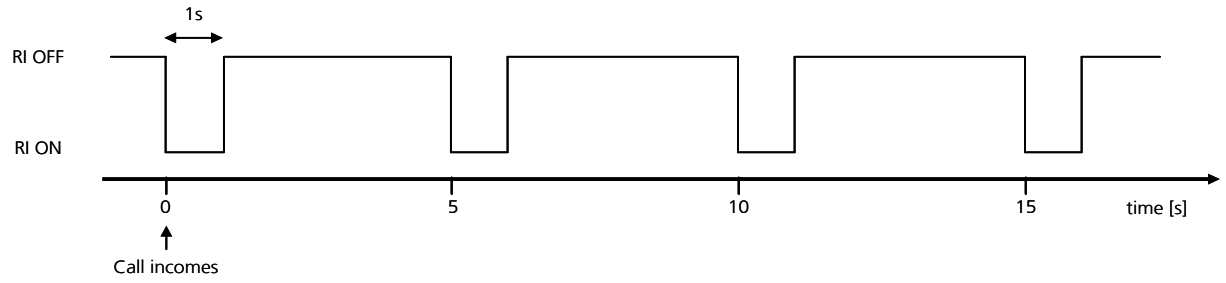

Figure 29: RI behavior at incoming call

The **RI** line is used to notify an SMS arrival. When the SMS arrives the **RI** line switches from OFF to ON for 1 second (see Figure 30).

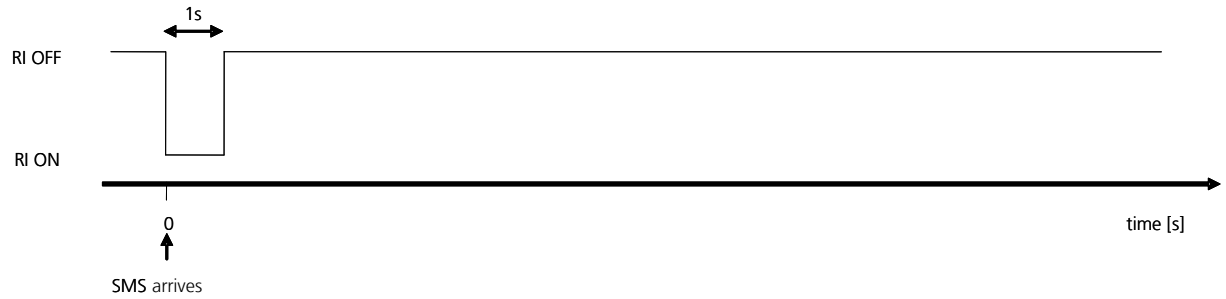

Figure 30: RI behavior at SMS arrival

1.11.1.3 UART application circuits

Full RS-232 Functionality

For complete RS-232 functionality conforming to [3] in DTE/DCE serial communication, the complete UART interface of the module (DCE) must be connected to the DTE as described in Figure 31.

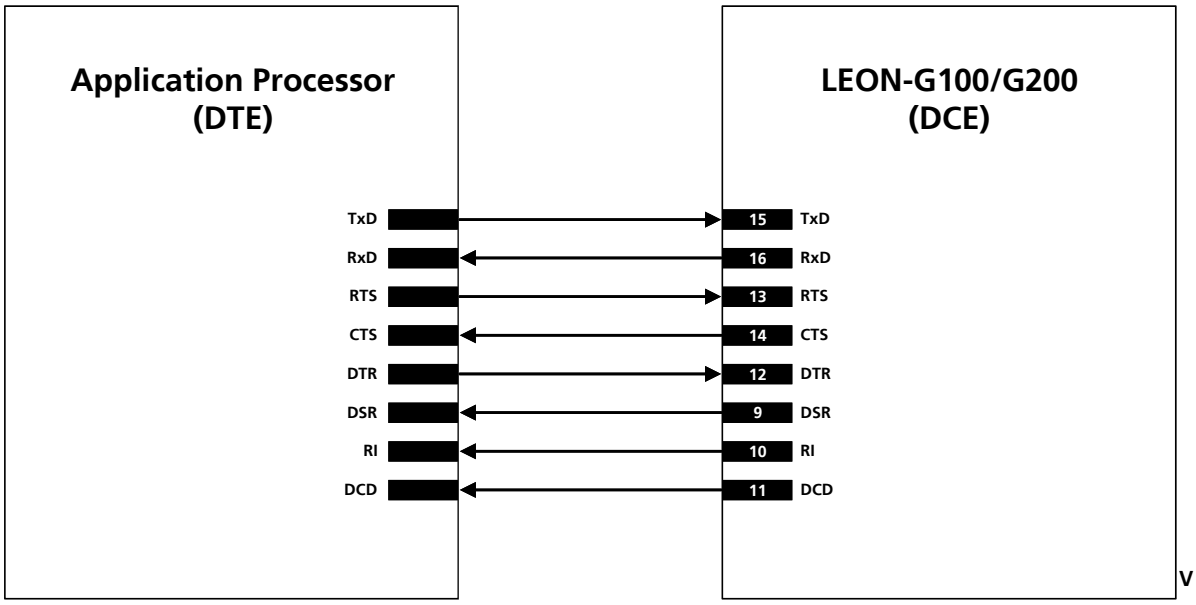

Fig. 30: UART interface application circuit with complete V.24 link in the DTE/DCE serial communication

Using TxD, RxD, RTS and CTS lines (not using the complete V.24 link)

Follow the application circuit described in Figure 31. In this case the HW flow-control is used. The module wakes up from default idle-mode to active-mode when data is received at the UART interface, since the HW flow control is enabled by default in the module. In the application circuit a loop from the module **DSR** output line to the module **DTR** input line must be implemented because the module needs **DTR** active (low electrical level) and **DSR** is active (low electrical level) once the module is switched on and the UART interface is enabled. The **DCD** and **RI** lines of the module can be left unconnected and floating.

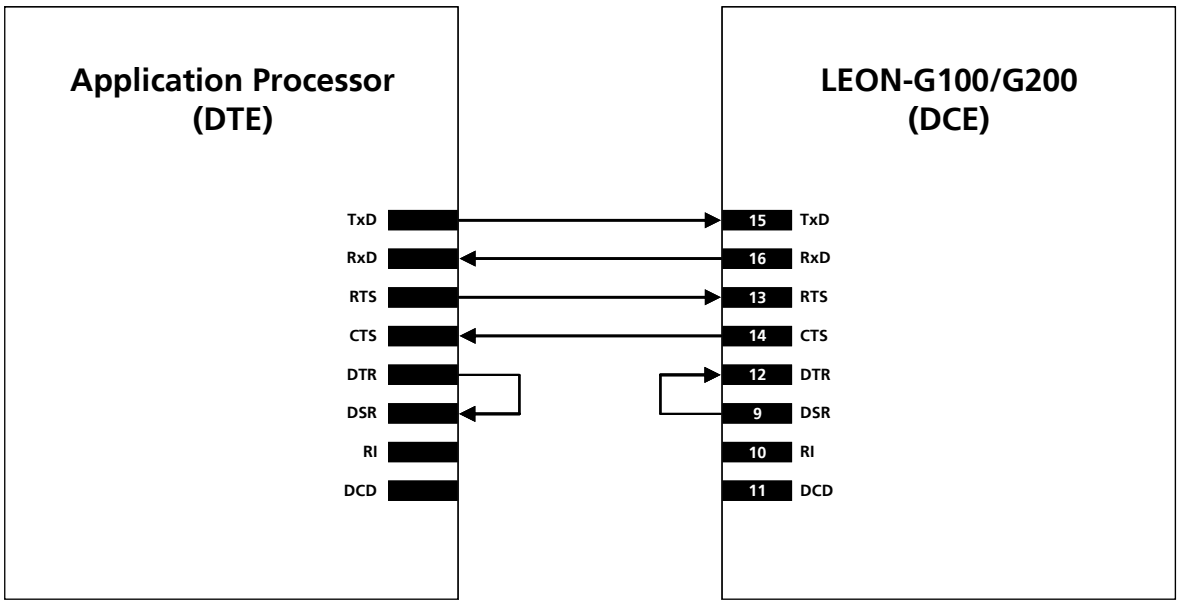

Figure 31: UART interface application circuit with partial V.24 link (4-wire) in the DTE/DCE serial communication

Using only TxD and RxD lines (not complete V24 link)

Follow the application circuit described in the Figure 32. In this case the HW flow control is not used. The module doesn't wake up from the default idle-mode to active-mode when data is received at the UART interface. Since the HW flow control is by default enabled in the module, data delivered by the DTE can be lost. In the application circuit a loop from the module **CTS** output line to the module **RTS** input line is provided

because the module needs **RTS** active (low electrical level) and **CTS** is active (low electrical level) when the module is in active mode and the UART interface is enabled. In the application circuit a loop from the module **DSR** output line to the module DTR input line is provided because the module needs **DTR** active (low electrical level) and **DSR** is active (low electrical level) once the module is switched on and the UART interface is enabled. The **DCD** and **RI** lines of the module can be left unconnected and floating. Also in this configuration the UART interface can be used as AT commands interface, for GPRS data and CSD data communication and for software upgrades, but without the HW flow control, data delivered by the DTE can be lost.

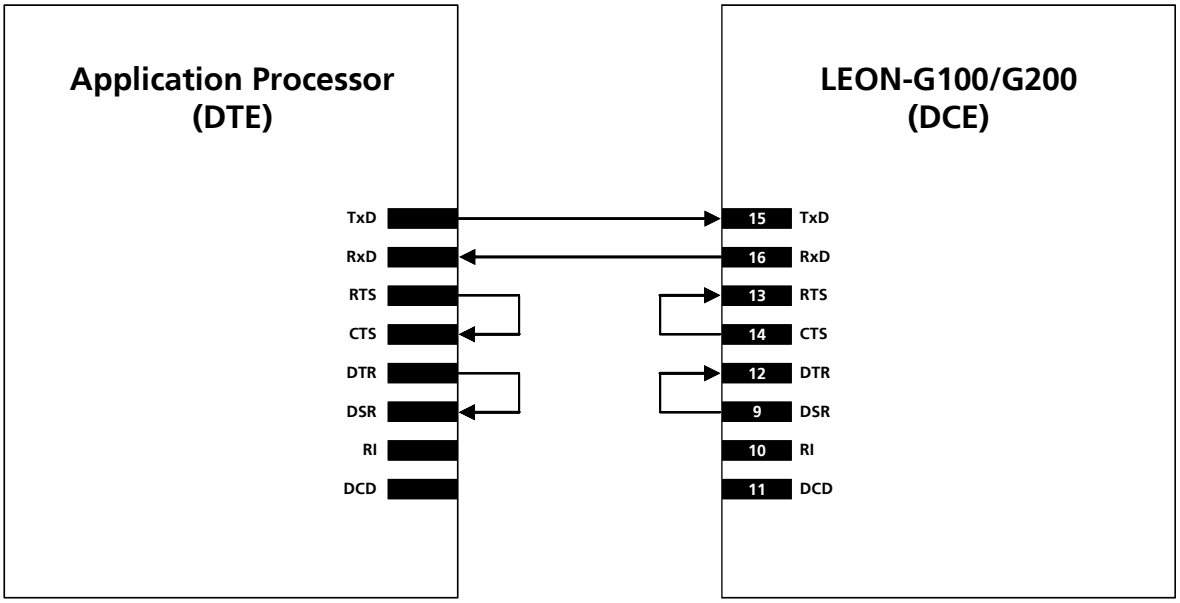

Figure 32: UART interface application circuit with partial V.24 link (2-wire) in the DTE/DCE serial communication

☞ To avoid an increase in module power consumption, any external signal connected to the UART must be set low or tri-stated when the module is in power-down mode. If the external signals in the application circuit connected to the UART cannot be set low or tri-stated, a multi channel digital switch (e.g. Texas Instruments SN74CB3Q16244) or a single channel analog switch (e.g.Texas Instruments TS5A3159 or Texas Instruments TS5A63157) must be inserted between the two-circuit connections and set to high impedance when the module is in power-down mode.

1.11.1.4 MUX Protocol (3GPP 27.010)

The module has a software layer with MUX functionality complaint with [9].

It is a data link protocol (layer 2 of OSI model) which uses HDLC-like framing and operates between the module (DCE) and the application processor (DTE). The protocol allows simultaneous sessions over the physical link, the UART. Each session consists of a stream of bytes transferring various kinds of data like SMS, CBS, GPRS, AT commands in general. This permits, for example, SMS to be transferred to the DTE when a data connection is in progress.

The following virtual channels are defined:

- Channel 0: MUX control
- Channel 1: reserve for GPS data
- Channel 2-5: free usage

1.11.2 DDC (I^2C) interface

1.11.2.1 Overview

An I^2C compatible Display Data Channel (DDC) interface is available with LEON-G100/G200 modules for serial communication. This interface is exclusively to access u-blox GPS receivers.

To be complaint with the I²C bus specifications, the module pads of the bus interface are open drain output and pull up resistors must be used. Since the pull-up resistors are not mounted on the module, they must be mounted externally. Resistor values must conform to the I²C bus specifications [10]. If LEON-G100/G200 modules are connected through the DDC bus to a single u-blox GPS receiver only (only one device is connected on the DDC bus), use a pull-up resistor of 4.7 kΩ. Pull-ups must be connected to a supply voltage of 2.85 V (typical), since this is the voltage domain of the DDC pins (for detailed electrical characteristics see the LEON-G100/G200 Data Sheet [1]).

DDC Slave-mode operation is not supported, the module can act as master only.

Two lines, serial data (**SDA**) and serial clock (**SCL**), carry information on the bus. **SCL** is used to synchronize data transfers, and **SDA** is the data line. Since both lines are open drain outputs, the DDC devices can only drive them low or leave them open. The pull-up resistor pulls the line up to the supply rail if no DDC device is pulling it down to GND. If the pull-ups are missing, **SCL** and **SDA** lines are undefined and the DDC bus will not work.

The signal shape is defined by the values of the pull-up resistors and the bus capacitance. Long wires on the bus will increase the capacitance. If the bus capacitance is increased, use pull-up resistors with lower nominal resistance value than 4.7 kΩ, to match the I²C bus specifications regarding rise and fall times of the signals [10].

☞ Capacitance must be limited on the bus to match the I²C specifications: connections should be routed as short as possible.

☞ If the pins are not used as DDC bus interface, they can be left unconnected.

1.11.2.2 Minimal connections

The minimal connections are illustrated in the Figure 33.

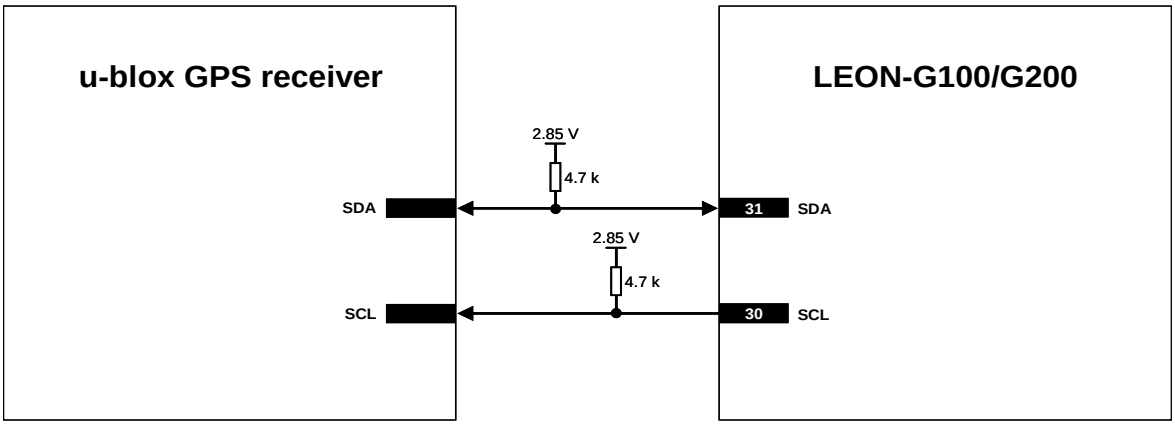

Figure 33: DDC interface application circuit (connection with a GPS module)

1.12 ADC input (LEON-G100 only)

One Analog to Digital Converter input is available (**ADC1**) and is configurable using u-blox AT commands (see u-blox AT Commands Manual [2]). The resolution of this converter is 12-bit with a single ended input range.

The electrical behavior of the measurement circuit in voltage mode can be modeled by a circuit equivalent to that shown in Figure 34. This includes a resistor (R_{eq}), voltage source (U_{eq}), analog preamplifier (with typical gain G=0.5), and a digital amplifier (with typical gain g_{ADC}=2048 LSB/V).

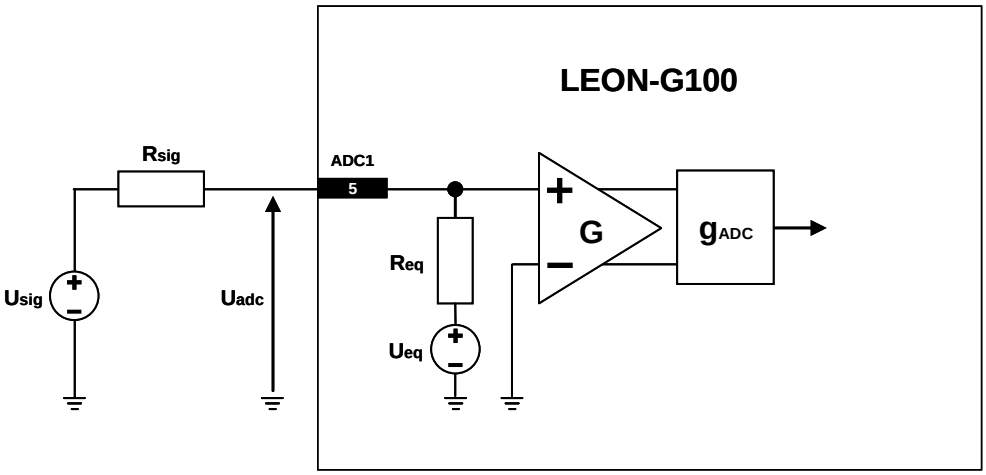

Figure 34: Equivalent network for ADC single-ended measurement

The LEON-G100 ADC software driver takes care of the parameters shown in Figure 34 (R_{eq}, U_{eq}, G, g_{ADC}). The voltage measured by the ADC is U_{adc}. If the voltage source (U_{sig}) has a significant internal resistance (R_{sig}) compared to the input resistance in measurement mode (R_{eq}) of the ADC, this should be taken into account and corrected.

☞ If an external voltage divider is implemented to increase the voltage range, check the input resistance in measurement mode (R_{eq}) of the ADC input and all the electrical characteristics.

The detailed electrical specification of the Analog to Digital Converter input are reported in the LEON-G100/G200 Data Sheet [1].

1.13 General Purpose Input/Output (GPIO)

LEON-G100/G200 modules provide two General Purpose Input/Output pins (**GPIO1**, **GPIO2**) which can be configured via u-blox AT commands (more details available in u-blox AT Commands Manual [2]).

GPIO2 is dedicated for connection to a u-blox GPS receiver: AT commands are used to drive the GPIO as output to wake up the u-blox GPS module. If LEON-G100/G200 module is not connected to a u-blox GPS module, GPIO2 can be used for general purposes.

Unused and unconnected GPIOs should be programmed to a fixed logic level to minimize module idle power consumption. Therefore set unused pins in GPIO output mode driving ground level.

☞ To avoid an increase of module power consumption any external signal connected to a GPIO must be set low or tri-stated when the module is in power-down mode. If the external signals in the application circuit connected to a GPIO cannot be set low or tri-stated, mount a multi channel digital switch (e.g. Texas Instruments SN74CB3Q16244) or a single channel analog switch (e.g. Texas Instruments TS5A3159 or TS5A63157) between the two-circuit connections and set to high impedance.

☞ For debug purposes, add a test point on the **GPIO1** pin even if this GPIO is not used.

1.14 Approvals

1.14.1 Compliance with FCC and IC Rules and Regulations

FCC Identifier for LEON-G100*:* **XPYLEONG100**

FCC Identifier for LEON-G100*:* **XPYLEONG100**

Industry Canada Certification Number LEON-G100 **: 8595A-LEONG100**

Industry Canada Certification Number LEON-G200 **: 8595A-LEONG200**

Manufacturers of **mobile** or **fixed** devices incorporating LEON-G100 / LEON-G200 modules are authorized to use the FCC Grants and Industry Canada Certificates of the LEON-G100 / LEON-G200 modules for their own final products according to the conditions referenced in the certificates.

The FCC Label shall in the above case be visible from the outside, or the host device shall bear a second label stating:

"Contains FCC ID: **XPYLEONG100**" resp. "Contains FCC ID **XPYLEONG200**".

IMPORTANT: Manufacturers of portable applications incorporating LEON-G100 / LEON-G200 modules are required to have their final product certified and apply for their own FCC Grant and Industry Canada Certificate related to the specific portable device. This is mandatory to meet the SAR requirements for portable devices.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

2 Design-In

This section provides a design-in checklist.

2.1 Schematic design-in checklist

The following are the most important points for a simple design-in check:

- ☑ **VCC** supply should be capable of delivering 2.5 A current bursts with low voltage drop.
- ☑ **VCC** supply should be clean, with very low ripple and noise.
- ☑ Do no connect DC/DC regulator output and Battery Pack on **VCC**, they are mutually exclusive.
- ☑ **V_CHARGE** and **CHARGE_SENSE** must be externally shorted (LEON-G200 only).
- ☑ The DC supply used as charger must be current limited as specified (LEON-G200 only).
- ☑ Do no leave **POWER_ON** floating: add a pull-up resistor.
- ☑ Insert a series inductor on each microphone lines and a 27 pF bypass capacitor on each audio line.
- ☑ Capacitance must be limited on each SIM signal to match the SIM specifications.
- ☑ Check that voltage level of connected digital pins does not exceed operating range.
- ☑ Check UART signals direction, since the signal names follow the ITU-T V.24 Recommendation.
- ☑ Add a proper pull-up resistor on each line of the DDC interface.
- ☑ Capacitance must be limited on each line of the DDC interface.
- ☑ Check the matching of the digital audio interface specifications to connect a proper device (LEON-G200 only).
- ☑ For debug purposes, add a test point on each I2S pin and on **GPIO1** also if they are not used.
- ☑ To avoid an increase of module current consumption in power down mode, any external signals connected to the module digital pins (UART interface, Digital Audio Interface, **HS_DET**, GPIOs) must be set low or tri-stated when the module is in power down mode.

Layout:

- ☑ Check 50 Ω impedance of **ANT** line.
- ☑ Ensure no coupling occurs with other noisy or sensitive signals.
- ☑ **VCC** line should be wide and short.
- ☑ Route **VCC** supply line away from sensitive analog signals.
- ☑ Avoid coupling of any noisy signals to microphone inputs lines.
- ☑ Ensure proper grounding.
- ☑ Consider “No-routing” areas for the Data Module footprint.
- ☑ Optimize placement for minimum length of RF line and closer path from DC source for **VCC**.

Antenna:

- ☑ Antenna should have 50 Ω impedance, V.S.W.R less then 3:1, recommended 2:1 on operating bands in deployment geographical area.
- ☑ Antenna should have built in DC resistor to ground to get proper Antenna detection functionality.

2.2 Design Guidelines for Layout

The following design guidelines must be met for optimal integration of LEON-G100/G200 modules on the final application board.

2.2.1 Layout guidelines per pin function

This section groups the LEON-G100/G200 pins by signal function and provides a ranking of importance in layout design.

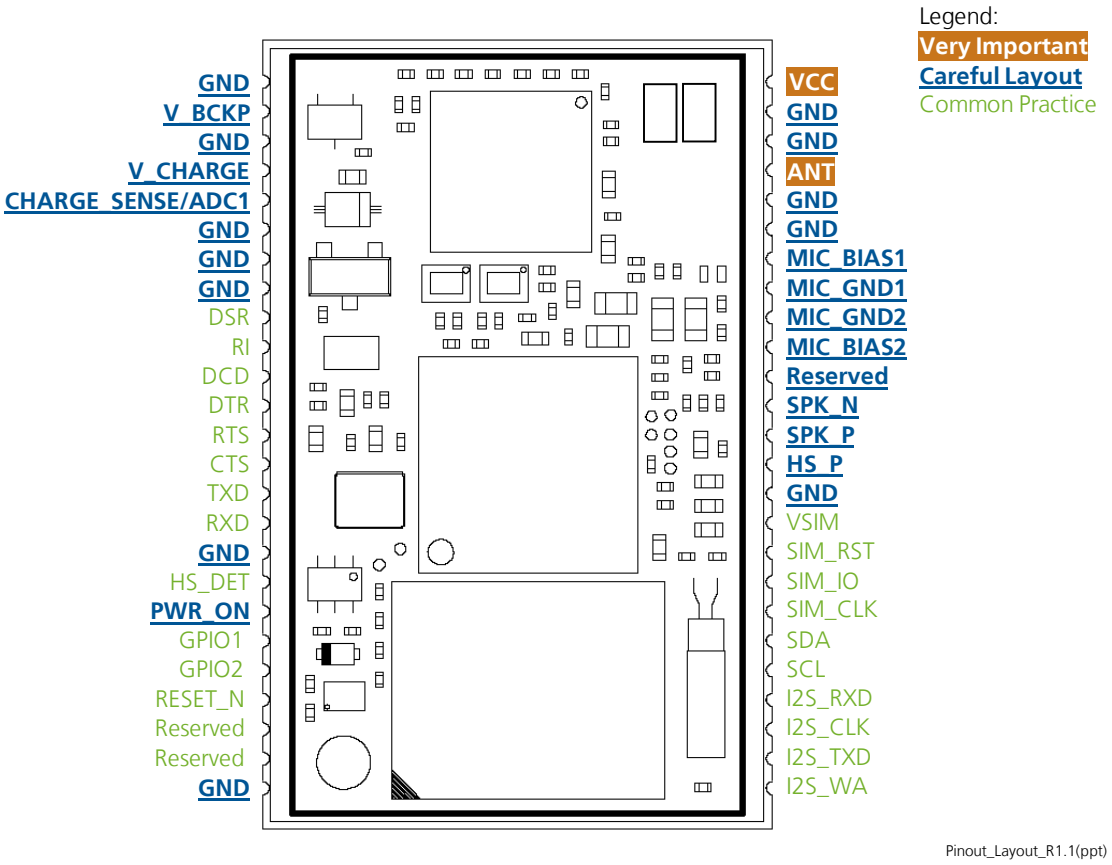

Figure 35: Module pin-out with highlighted functions

Rank	Function	Pin(s)	Layout	Remarks
1st	**RF Antenna In/out**	**ANT**	**Very Important**	Design for 50 Ω characteristic impedance. See section 2.2.1.1
2nd	**DC Supply**	**VCC**	**Very Important**	**VCC** line should be wide and short. Route away from sensitive analog signals. See section 2.2.1.2
3rd	**Analog Audio**		**Careful Layout**	Avoid coupling with noisy signals See section 2.2.1.3
	Audio Inputs	**MIC_BIAS1, MIC_GND1, MIC_BIAS2, MIC_GND2**		
	Audio Outputs	**SPK_P, SPK_N, HS_P**		
4th	**Ground**	**GND**	**Careful Layout**	Provide proper grounding. See section 2.2.1.4
5th	**Charger**	**V_CHARGE, CHARGE_SENSE**	**Careful Layout**	Check Charger line width. See section 2.2.1.5
6th	**Sensitive Pin :**		**Careful Layout**	Avoid coupling with noisy signals. See section 2.2.1.6
	Backup Voltage	**V_BCKP**		
	A to D Converter (If implemented)	**ADC1**		
	Power On	**PWR_ON**		
7th	**Digital pins :**		Common Practice	Follow common practice rules for digital pin routing See section 2.2.1.7
	SIM Card Interface	VSIM, SIM_CLK, SIM_IO, SIM_RST		
	Digital Audio	I2S_CLK, I2S_RXD, I2S_TXD, I2S_WA		
	DDC	SCL, SDA		
	UART	TXD, RXD, CTS, RTS, DSR, RI, DCD, DTR		
	External Reset	RESET_N		
	General Purpose I/O	GPIO1, GPIO2		

Table 8: Pin list in order of decreasing importance for layout design

2.2.1.1 RF Antenna connection

The RF antenna connection pin **ANT** is very critical in layout design. The PCB line must be designed to provide 50 Ω characteristic impedance and minimum loss up to radiating element.

- Provide proper transition between the **ANT** pad to application board PCB
- Increase GND keep-out for **ANT** pin to at least 250 µm up to adjacent pads metal definition and up to 500 µm on the area below the Data Module
- Add GND keep-out on buried metal layers below antenna pad if top-layer to buried layer dielectric thickness is below 200 µm
- The transmission line up to antenna connector or pad may be a micro strip or a stripline. In any case must be designed to achieve 50 Ω characteristic impedance;
- Microstrip lines are usually easier to implement and the reduced number of layer transitions up to antenna connector simplifies the design and diminishes reflection losses. However, the electromagnetic field extends to the free air interface above the stripline and may interact with other circuitry
- Buried stripline exhibits better shielding to incoming and generated interferences. Therefore are preferred for sensitive application. In case a stripline is implemented, carefully check that the via pad-stack does not couple with other signals on the crossed and adjacent layers
- Minimize the transmission line length; the insertion loss should be minimized as much as possible, in the order of a few tenths of a dB
- The transmission line should not have abrupt change to thickness and spacing to GND, but must be uniform and routed as smoothly as possible

- The transmission line must be routed in a section of the PCB where minimal interference from noise sources can be expected
- Route **ANT** line far from other sensitive circuits as it is a source of electromagnetic interference
- Avoid coupling with **VCC** routing and analog Audio lines
- Ensure solid metal connection of the adjacent metal layer on the PCB stack-up to main ground layer
- Add GND vias around transmission line
- Ensure no other signals are routed parallel to transmission line, or that other signals cross on adjacent metal layer
- If the distance between the transmission line and the adjacent GND area (on the same layer) does not exceed 5 times the track width of the micro strip, use the "Coplanar Waveguide" model for 50 Ω characteristic impedance calculation
- Don't route microstrip line below discrete component or other mechanics placed on top layer
- When terminating transmission line on antenna connector (or antenna pad) it is very important to strictly follow the connector manufacturer's recommended layout
- GND layer under RF connectors and close to buried vias should be cut out in order to remove stray capacitance and thus keep the RF line 50 Ω. In most cases the large active pad of the integrated antenna or antenna connector needs to have a GND keep-out at least on first inner layer to reduce parasitic capacitance to ground. Note that the layout recommendation is not always available from connector manufacturer: e.g. the classical SMA Pin-Through-Hole needs to have GND cleared on all the layers around the central pin up to annular pads of the four GND posts. Check 50 Ω impedance of **ANT** line
- Ensure no coupling occurs with other noisy or sensitive signals

2.2.1.2 Main DC supply connection

The DC supply of LEON-G100/G200 modules is very important for the overall performance and functionality of the integrated product. For detailed description check the design guidelines in section 1.5.2. Some main characteristics are:

- **VCC** connection may carry a maximum burst current in the order of 2.5 A. Therefore, it is typically implemented as a wide PCB line with short routing from DC supply (DC-DC regulator, battery pack, etc)
- The module automatically initiates an emergency shutdown if supply voltage drops below hardware threshold. In addition, reduced supply voltage can set a worst case operation point for RF circuitry that may behave incorrectly. It follows that each voltage drop in the DC supply track will restrict the operating margin at the main DC source output. Therefore, the PCB connection has to exhibit a minimum or zero voltage drop. Avoid any series component with Equivalent Series Resistance (ESR) greater than a few mΩs
- Given the large burst current, **VCC** line is a source of disturbance for other signals. Therefore route **VCC** through a PCB area separated from sensitive analog signals. Typically it is good practice to interpose at least one layer of PCB ground between **VCC** track and other signal routing
- The **VCC** supply current supply flows back to main DC source through GND as ground current: provide adequate return path with suitable uninterrupted ground plane to main DC source;
- A tank capacitor with low ESR is often used to smooth current spikes. This is most effective when placed as close as possible to **VCC**. From main DC source, first connect the capacitor and then **VCC**. If the main DC source is a switching DC-DC converter, place the large capacitor close to the DC-DC output and minimize the **VCC** track length. Otherwise consider using separate capacitors for DC-DC converter and LEON-G100/G200 tank capacitor. Note that the capacitor voltage rating may be adequate to withstand the charger over-voltage if battery-pack is used
- **VCC** is directly connected to the RF power amplifier. Add capacitor in the pF range from **VCC** to GND along the supply path
- Since **VCC** is directly connected to RF Power Amplifier, voltage ripple at high frequency may result in unwanted spurious modulation of transmitter RF signal. This is especially seen with switching DC-DC converters, in which case it is better to select the highest operating frequency for the switcher and add a large L-C filter before connecting to LEON-G100/G200 in the worst case

- The large current generates a magnetic field that is not well isolated by PCB ground layers and which may interact with other analog modules (e.g. **VCO**) even if placed on opposite side of PCB. In this case route **VCC** away from other sensitive functional units
- The typical GSM burst has a periodic nature of approx. 217 Hz, which lies in the audible audio range. Avoid coupling between **VCC** and audio lines (especially microphone inputs)
- If **VCC** is protected by transient voltage suppressor / reverse polarity protection diode to ensure that the voltage maximum ratings are not exceeded, place the protecting device along the path from the DC source toward LEON-G100/G200, preferably closer to the DC source (otherwise functionality may be compromised)
- **VCC** pad is longer than other pads, and requires a "No-Routing" area for any other signals on the top layer of the application board PCB, below the LEON-G100/G200
- **VCC** line should be wide and short
- Route away from sensitive analog signals

2.2.1.3 Analog Audio

Accurate analog audio design is very important to obtain clear and high quality audio. The GSM signal burst has a repetition rate of 271 Hz that lies in the audible range. A careful layout is required to reduce the risk of noise pickup from audio lines due to both **VCC** burst noise coupling and RF detection.

Analog audio is separated in the two paths,

1. Audio Input (Uplink path): **MIC_BIASx**, **MIC_GNDx**
2. Audio Outputs (Downlink path): **SPK_P / SPK_N**, **HS_P**

The most sensitive is the Uplink path, since the analog input signals are in the µV range. The two microphone inputs have the same electrical characteristics, and it is recommended to implement their layout with the same routing rules.

- Avoid coupling of any noisy signals to microphone inputs lines
- It is strongly recommended to route MIC signals away from battery and RF antenna lines. Try to skip fast switching digital lines as well
- Keep ground separation from other noisy signals. Use an intermediate GND layer or vias wall for coplanar signals
- **MIC_BIAS** and **MIC_GND** carry also the bias for external electret active microphone. Verify that microphone is connected with right polarity, i.e. **MIC_BIAS** to the pin marked "+" and **MIC_GND** (zero Volt) to the chassis of the device;
- Despite different DC level, **MIC_BIAS** and **MIC_GND** are sensed differentially within the module. Therefore they should be routed as a differential pair of **MIC_BIAS** up to the active microphone
- Route **MIC_GND** with dedicated line together with **MIC_BIAS** up to active microphone. Note that **MIC_GND** is grounded internally within module and does not need external connection to GND
- Cross other signals lines on adjacent layers with 90° crossing
- Place bypass capacitor for RF very close to active microphone. The preferred microphone should be designed for GSM applications which typically have internal built-in bypass capacitor for RF very close to active device. If the integrated FET detects the RF burst, the resulting DC level will be in the pass-band of the audio circuitry and cannot be filtered by any other device
- If DC decoupling is required, consider that the input impedance of microphone lines is in the kΩ range. Therefore, series capacitors with sufficiently large value to reduce the high-pass cut-off frequency of the equivalent high-pass RC filter

Output Audio lines have two separated configurations.

SPK_P / **SPK_N** are high level balanced output. They are DC coupled and must be used with a speaker connected in bridge configuration.

- Route **SPK_P** / **SPK_N** as differential pair, to reduce differential noise pick-up. The balanced configuration will help reject the common mode noise
- If audio output is directly connected to speaker transducer, given the low load impedance of its load, then consider enlarging PCB lines to reduce series resistive losses
- **HS_P** is single ended analog audio referenced to GND. Reduce coupling with noisy lines as this Audio output line does not benefit from common mode noise rejection of **SPK_P** / **SPK_N**
- Use twisted pair cable for balanced audio usage, shielded cable for unbalanced connection to speaker
- If DC decoupling is required, a large capacitor needs to be used, typically in the µF range, depending on the load impedance, in order not to increase the lower cut-off frequency due to its High-Pass RC filter response

2.2.1.4 Module grounding

Good connection of the module with application board solid ground layer is required for correct RF performance. It significantly reduces EMC issues and provides a thermal heat sink for the module.

- Connect each **GND** pin with application board solid GND layer. It is strongly recommended that each **GND** pad surrounding **VCC** and **ANT** pins have one or more dedicated via down to application board solid ground layer. The same applies to **GND** pins on the opposite side close to Charger pins
- If Application board is a multilayer PCB, then it is required to tight together each GND area with complete via stack down to main board ground layer
- It is recommended to implement one layer of the application board as ground plane
- Good grounding of **GND** pads will also ensure thermal heat sink. This is critical during call connection, when the real network commands the module to transmit at maximum power: proper grounding helps prevent module overheating.

2.2.1.5 Charger Layout

If battery charger is implemented, **V_CHARGE** must withstand the charge current (typically in the order of several hundred mA) continuous current sink. Voltage drop is not as critical as for **VCC**, but dimension the line width adequately to support the charge current without excessive loss that may lead to increase in PCB temperature.

CHARGE_SENSE senses the charger voltage: it sinks a few µA. Therefore its line width is not critical. Since it is an analog input, it must be connected to **V_CHARGE** away from noisy sources.

2.2.1.6 Other Sensitive pins

A few other pins on the LEON-G100/G200 require careful layout.

- **Backup battery (V_BCKP):** avoid injecting noise on this voltage domain as it may affect the stability of sleep oscillator
- **Analog-to-Digital Converter (ADC1)**: it is a high impedance analog input; the conversion accuracy will be degraded if noise injected. Low-pass filter may be used to improve noise rejection; typically L-C tuned for RF rejection gives better results;
- **Power On (PWR_ON):** is the digital input for power-on of the LEON-G100/G200. It is implemented as high impedance input. Ensure that the voltage level is well defined during operation and no transient noise is coupled on this line, otherwise the module may detect a spurious power-on request

2.2.1.7 Digital pins

- **External Reset (RESET_N):** input for external reset, a logic low voltage will reset the module
- **SIM Card Interface (VSIM, SIM_CLK, SIM_IO, SIM_RST)**: the SIM layout may be critical if the SIM card is placed far away from LEON-G100/G200 or in close vicinity of RF antenna. In the first case the long connection may radiate higher harmonic of digital data. In the second case the same harmonics may be picked up and create self-interference that can reduce the sensitivity of GSM Receiver channels whose carrier frequency is coincident with harmonic frequencies. In the later case using RF bypass capacitors on the digital line will mitigate the problem. In addition, since the SIM card typically accesses by the end use, it may be subjected to ESD discharges: add adequate ESD protection to improve the robustness of the digital pins within the module. Remember to add such ESD protection along the path between SIM holder toward the module
- **Digital Audio (I2S_CLK, I2S_RX, I2S_TX, I2S_WA)**: the I2S interface requires the same consideration regarding electro-magnetic interference as the SIM card. Keep the traces short and avoid coupling with RF line or sensitive analog inputs;
- **DDC (SCL, SDA)**: the DDC interface requires the same consideration regarding electro-magnetic interference as for SIM card. Keep the traces short and avoid coupling with RF line or sensitive analog inputs;
- **UART (TXD, RXD, CTS, RTS, DSR, RI, DCD, DTR)**: the serial interface require the same consideration regarding electro-magnetic interference as for SIM card. Keep the traces short and avoid coupling with RF line or sensitive analog inputs.

2.2.2 Footprint and paste mask

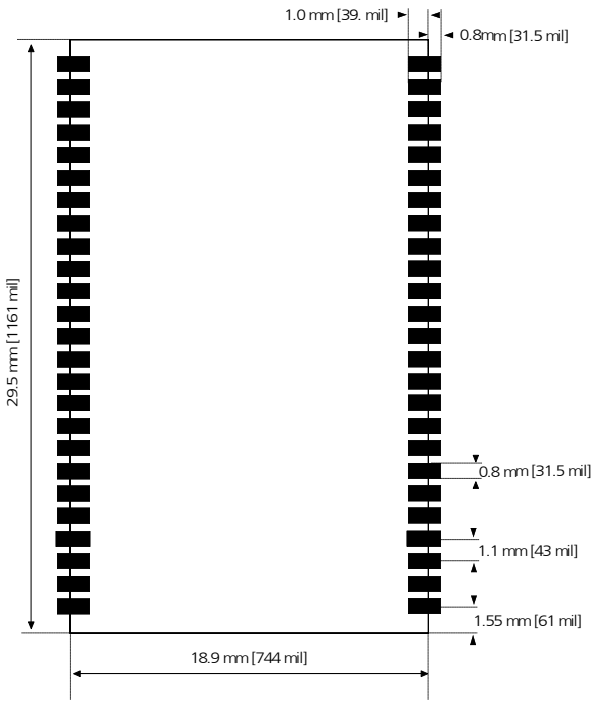

Figure 36: LEON-G100/G200 footprint

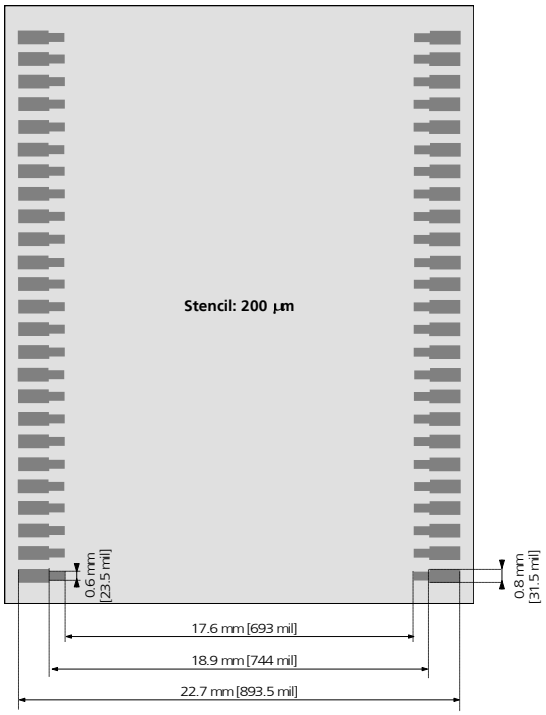

Figure 37: LEON-G100/G200 paste mask

To improve the wetting of the half vias, reduce the amount of solder paste under the module and increase the volume outside of the module by defining the dimensions of the paste mask to form a T-shape (or equivalent) extending beyond the Copper mask. The solder paste should have a total thickness of 200 µm.

☞ The paste mask outline needs to be considered when defining the minimal distance to the next component.

☞ The exact geometry, distances, stencil thicknesses and solder paste volumes must be adapted to the specific production processes (e.g. soldering etc.) of the customer.

The bottom layer of LEON-G100/G200 shows some unprotected copper areas for **GND** and **VCC** signals, plus **GND** keep-out for internal RF signals routing.

☞ Consider "No-routing" areas for the LEON-G100/G200 footprint as follows:

1. Ground copper and signals keep-out below LEON-G100/G200 on Application Motherboard due to **VCC** area, RF **ANT** pin and exposed GND pad on module bottom layer (see Figure 38);
2. Signals Keep-Out below module on Application Motherboard due to GND opening on LEON-G100/G200 bottom layer for internal RF signals (see Figure 39).

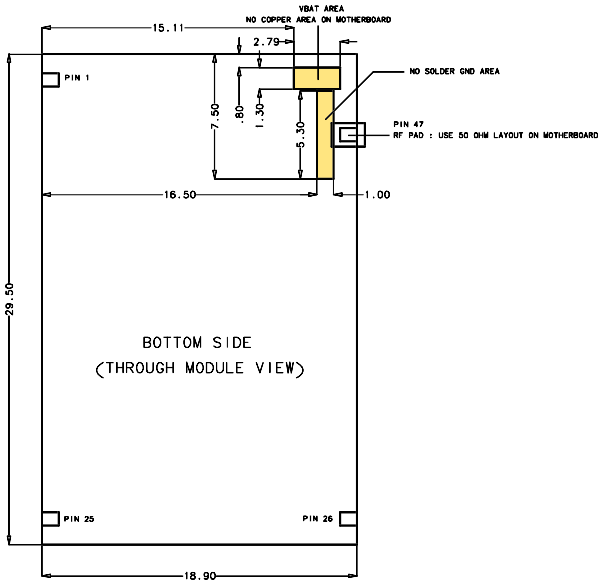

Figure 38: Ground copper and signal keep-out below data module on application motherboard due to due to VCC area, RF ANT pin and exposed GND pad on data module bottom layer

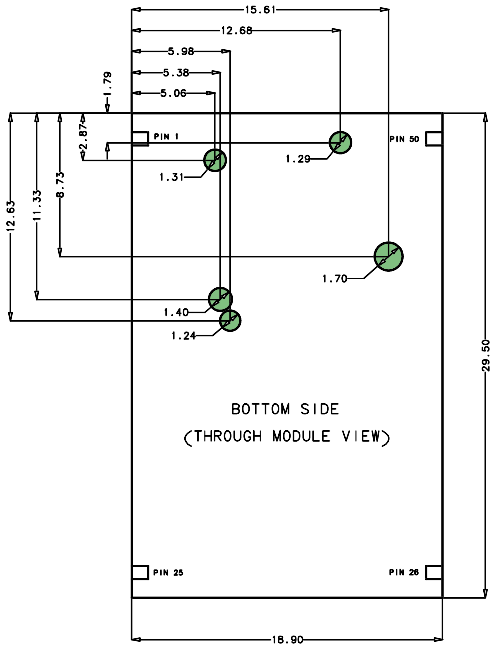

Figure 39: Signals keep-out below data module on application motherboard due to GND opening on data module bottom layer for internal RF signals

Routing below LEON-G100/G200 on application motherboard is generally possible but not recommended: in addition to the required keep-out defined before, consider that the insulation offered by the solder mask painting may be weakened corresponding to micro-vias on LEON-G100/G200 bottom layer, thus increasing the risk of short to GND if the application motherboard has unprotected signal routing on same coordinates.

2.2.3 Placement

Optimize placement for minimum length of RF line and closer path from DC source for **VCC**.

2.3 Module thermal resistance

The Case-to-Ambient thermal resistance (R_{C-A}) of the module, with the LEON-G100/G200 mounted on a 130 x 110 x 1.6 mm FR4 PCB with a high coverage of copper (e.g. the EVK-G25H evaluation kit) in still air conditions is equal to 14°C/W.

With this Case-to-Ambient thermal resistance, the increase of the module temperature is:

- Around 12°C when the module transmits at the maximum power level during a GSM call in the GSM/EGSM bands;
- Around 17°C when the module transmits at the maximum power level during a GPRS data transfer (2 Tx + 3 Rx slots) in the GSM/EGSM bands;

☞ Case-to-Ambient thermal resistance value will be different than the one provided if the module is mounted on a PCB with different size and characteristics.

2.4 Antenna guidelines

Antenna characteristics are essential for good functionality of the module. The radiating performance of antennas have direct impact on the reliability of connection over the Air Interface. A bad termination of **ANT** can result in poor performance of the module.

The following parameters should be checked:

Item	Recommendations
Impedance	50 Ω
Frequency Range	Depends on the Mobile Network used. GSM900: 880..960 MHz GSM1800: 1710..1880 MHz GSM850: 824..894 MHz GSM1900: 1850..1990 MHz
Input Power	>2 W peak
V.S.W.R	<2:1 recommended, <3:1 acceptable
Return Loss	S_{11}<-10 dB recommended, S_{11}<-6 dB acceptable
Gain	<3 dBic

Table 9: General recommendation for GSM antenna

GSM antennas are typically available as:

- Linear monopole: typical for fixed application. The antenna extends mostly as a linear element with a dimension comparable to lambda/4 of the lowest frequency of the operating band. Magnetic base may be available. Cable or direct RF connectors are common options. The integration normally requires the fulfillment of some minimum guidelines suggested by antenna manufacturer
- Patch-like antenna: better suited for integration in compact designs (e.g. mobile phone). They are mostly custom designs where the exact definition of the PCB and product mechanical design is fundamental for tuning of antenna characteristics

For integration observe these recommendations:

- Ensure 50 Ω antenna termination, minimize the V.S.W.R. or return loss, as this will optimize the electrical performance of the module. See section 2.4.1
- Select antenna with best radiating performance. See section 2.4.2
- If a cable is used to connect the antenna radiating element to application board, select a short cable with minimum insertion loss. The higher the additional insertion loss due to low quality or long cable, the lower the connectivity
- Follow the recommendations of the antenna manufacturer for correct installation and deployment
- Do not include antenna within closed metal case
- Do not place antenna in close vicinity to end user since the emitted radiation in human tissue is limited by S.A.R. regulatory requirements
- Do not use directivity antenna since the electromagnetic field radiation intensity is limited in some countries
- Take care of interaction between co-located RF systems since the GSM transmitted power may interact or disturb the performance of companion systems
- Place antenna far from sensitive analog systems or employ countermeasures to reduce electromagnetic compatibility issues that may arise

2.4.1 Antenna termination

LEON-G100/G200 modules are designed to work on a 50 Ω load. However, real antennas have no perfect 50 Ω load on all the supported frequency bands. Therefore, in order to as much as possible reduce performance degradation due to antenna mismatch, the following requirements should met:

Measure the antenna termination with a network analyzer: connect the antenna through a coaxial cable to the measurement device, the $|S_{11}|$ indicates which portion of the power is delivered to antenna and which portion is reflected by the antenna back to the modem output.

A good antenna should have a $|S_{11}|$ below -10 dB over the entire frequency band. Due to miniaturization, mechanical constraints and other design issues, this value will not be achieved. A value of $|S_{11}|$ of about -6 dB - (in the worst case) - is acceptable.

Figure 40 shows an example of this measurement:

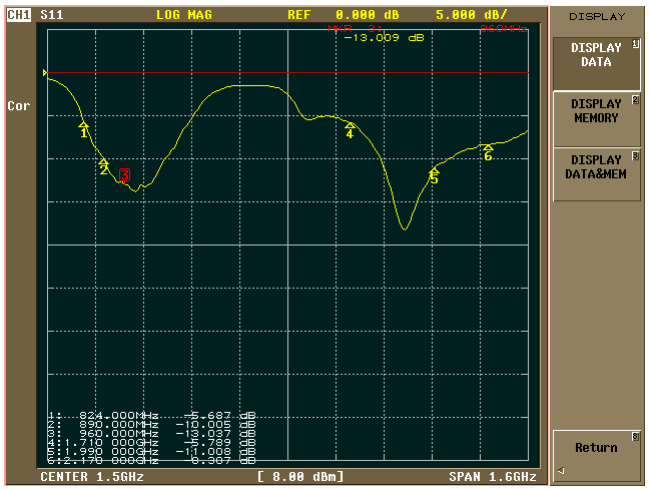

Figure 40: |S11| sample measurement of a penta-band antenna that covers in a small form factor the 4 GSM bands (850 MHz, 900 MHz, 1800 MHz and 1900 MHz) and the UMTS Band I

Fig 41 shows comparable measurements performed on a wideband antenna. The termination is better, but the size of the antenna is considerably larger.

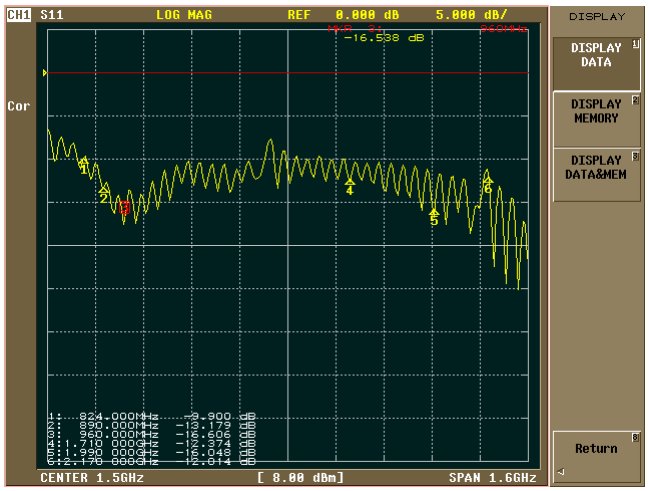

Figure 41: $|S_{11}|$ sample measurement of a wideband antenna

2.4.2 Antenna radiation

An indication of the radiated power by the antenna can be approximated by measuring the $|S_{2\backslash}|$ from a target antenna to the measurement antenna, measured with a network analyzer using a wideband antenna. Measurements should be done at a fixed distance and orientation. Compare the results to measurements performed on a known good antenna. Figure 42 through 45 show measurement results. A wideband log periodic-like antenna was used, and the comparison was done with a half lambda dipole tune on 900 MHz frequency. The measurements show both the $|S_{11}|$ and $|S_{21}|$ for penta-band internal antenna and for the wideband antenna.

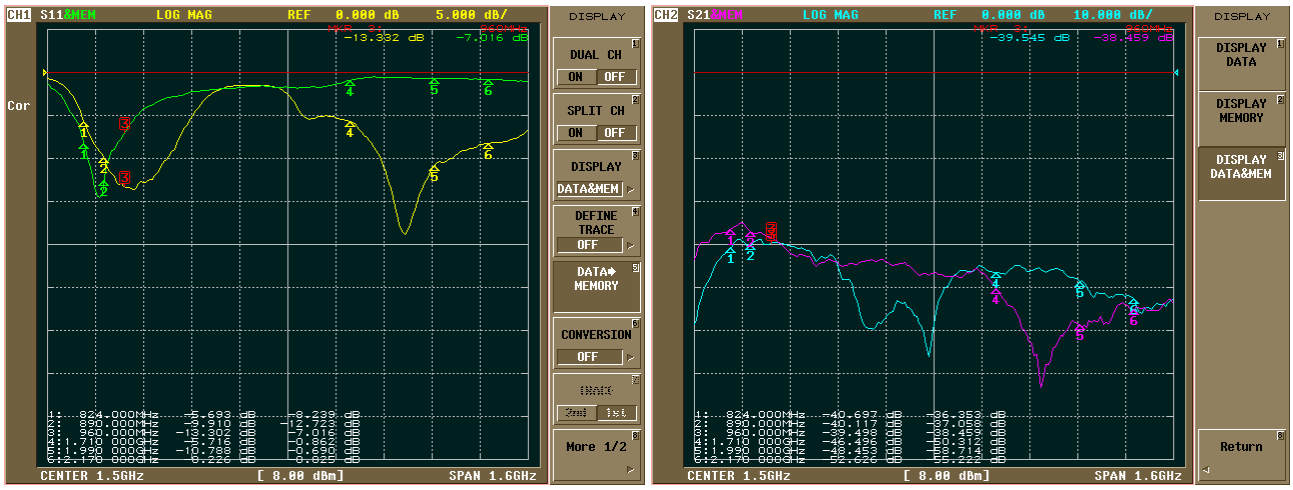

Figure 42 and 43: $|S_{11}|$ and $|S_{21}|$ comparison between a 900 MHz tuned half wavelength dipole and a penta-band internal antenna, if $|S_{21}|$ like in marker 3 area are similar the target antenna performances are good

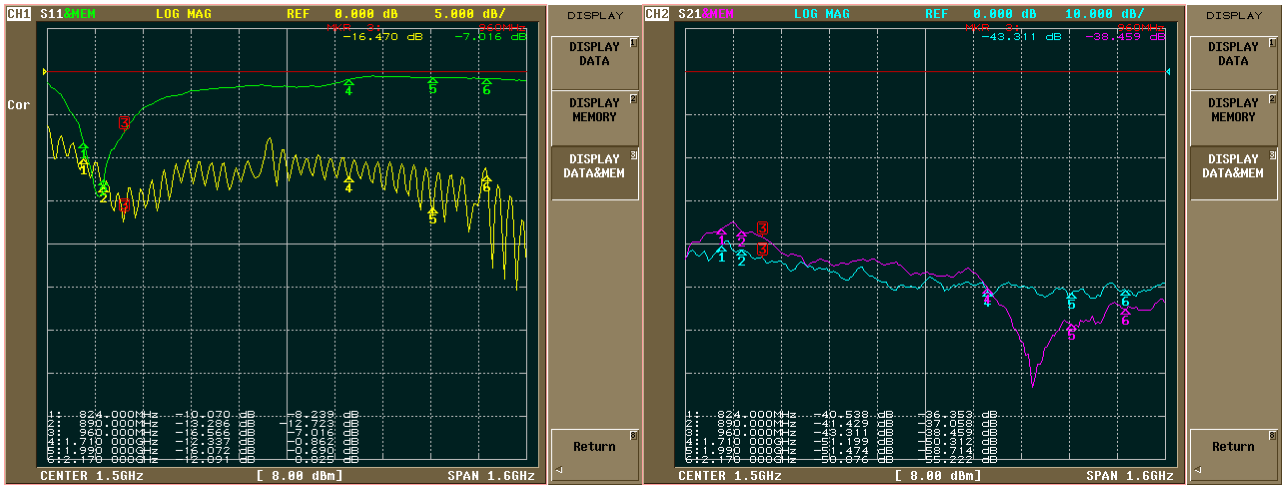

Figure 44 and 45: $|S_{11}|$ and $|S_{21}|$ comparison between a 900 MHz tuned half wavelength dipole and a wideband commercial antenna, if $|S_{21}|$ like in marker 1/2 area are similar 5 dB better in the dipole case, so the wideband antenna radiation is considerably less

☞ For good antenna radiation performance antenna dimensions should be comparable to a quarter of the wavelength. Different types of antenna that can be used for the module, many of them (e.g. patch antennas, monopole) are based on a resonating element that works in combination with a ground plane. The ground plane, ideally infinite, can be reduced down to a minimum size that must be similar to the quarter of the wavelength of the minimum frequency that has to be radiated (transmitted/received). Numerical sample: frequency 1 GHz → wavelength 30 cm → minimum ground plane (or antenna size) 7.5 cm. Below this size, the antenna efficiency is reduced.

2.4.3 Antenna detection functionality

The internal antenna detect circuit is based on DC voltage measurement at **ANT**. The module may inject a known DC current on **ANT** pin, to do resistance measurement.

To achieve good antenna detection functionality, use an RF antenna with built-in resistor from **ANT** signal to GND, or implement an equivalent solution with a circuit between the antenna cable connection and the radiating element as shown in Fig. 46.

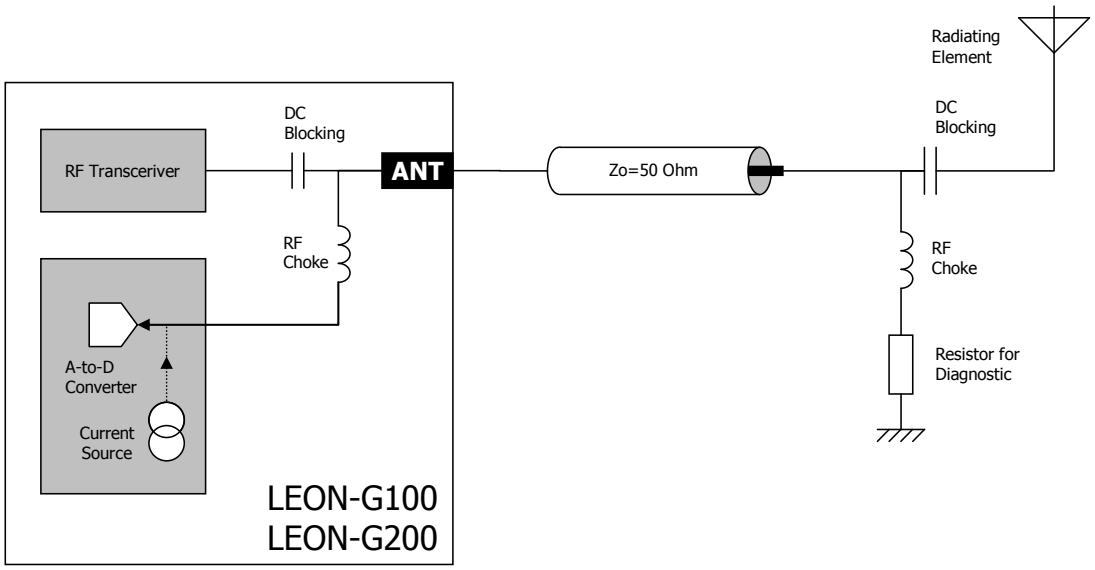

Figure 46: Antenna Detection circuit

LEON-G100/G200 modules will report the measured value (ohmic resistance or voltage level) seen at **ANT**. Values above the expected range indicate that the antenna has been disconnected. Values below the expected range indicate that RF connection is shorted to GND.

3 Handling and soldering

3.1 Packaging, shipping, storage and moisture preconditioning

For information pertaining to reels and tapes, Moisture Sensitivity levels (MSD), shipment and storage information, as well as drying for preconditioning see the LEON-G100/G200 Data Sheet [1].

3.2 Processing

3.2.1 Soldering paste

Use of "No Clean" soldering paste is strongly recommended, as it does not require cleaning after the soldering process has taken place. The paste listed in the example below meets these criteria.

Soldering Paste:	LFSOLDER TLF-206-93F (Tamura Kaken (UK) Ltd.)
Alloy specification:	Sn 95.5/ Ag 3.9/ Cu 0.6 (95.5% Tin/ 0.6 % Silver/ 0.6% Copper)
Melting Temperature:	216 - 221°C
Stencil Thickness:	150 µm for base boards

The final choice of the soldering paste depends on the approved manufacturing procedures.

The paste-mask geometry for applying soldering paste should meet the recommendations in section 2.2.2

☞ The quality of the solder joints on the connectors ('half vias') should meet the appropriate IPC specification.

3.2.2 Reflow soldering

A convection type-soldering oven is strongly recommended over the infrared type radiation oven. Convection heated ovens allow precise control of the temperature and all parts will be heated up evenly, regardless of material properties, thickness of components and surface color.

Consider the "IPC-7530 Guidelines for temperature profiling for mass soldering (reflow and wave) processes, published 2001".

Preheat phase

Initial heating of component leads and balls. Residual humidity will be dried out. Please note that this preheat phase will not replace prior baking procedures.

- Temperature rise rate: 1 - 4°C/s — If the temperature rise is too rapid in the preheat phase it may cause excessive slumping.
- Time: 60 – 120 seconds — If the preheat is insufficient, rather large solder balls tend to be generated. Conversely, if performed excessively, fine balls and large balls will be generated in clusters.
- End Temperature: 150 - 200°C — If the temperature is too low, non-melting tends to be caused in areas containing large heat capacity.

Heating/ reflow phase

The temperature rises above the liquidus temperature of 216 - 221°C. Avoid a sudden rise in temperature as the slump of the paste could become worse.

- Limit time above 220°C liquidus temperature: 20 - 40 s
- Peak reflow temperature: 230 - 250°C

Cooling phase

A controlled cooling avoids negative metallurgical effects (solder becomes more brittle) of the solder and possible mechanical tensions in the products. Controlled cooling helps to achieve bright solder fillets with a good shape and low contact angle.

- Temperature fall rate: max 3°C / s

☞ To avoid falling off, LEON-G100/G200 modules should be placed on the topside of the motherboard during soldering.

The final soldering temperature chosen at the factory depends on additional external factors like choice of soldering paste, size, thickness and properties of the base board, etc. Exceeding the maximum soldering temperature in the recommended soldering profile may permanently damage the module.

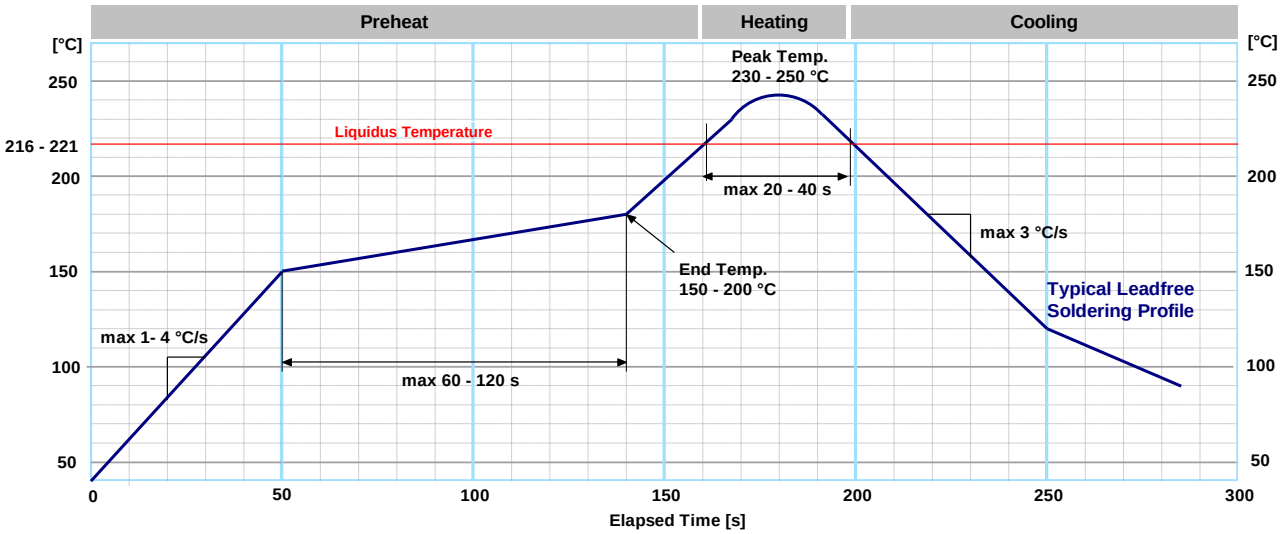

Figure 47: Recommended soldering profile

☞ When soldering lead-free (LEON-G100/G200) modules in a leaded process, check the following temperatures:

PB- Technology Soaktime: 40-80 sec

Time above Liquidus: 40-90 sec

Peak temperature: 225-235°C

☞ LEON-G100/G200 modules must not be soldered with a damp heat process.

3.2.3 Optical inspection

After soldering the LEON-G100/G200 module, inspect the modules optically to verify that he module is properly aligned and centered.

3.2.4 Cleaning

Cleaning the soldered modules is not recommended. Residues underneath the modules cannot be easily removed with a washing process.

- Cleaning with water will lead to capillary effects where water is absorbed in the gap between the baseboard and the module. The combination of residues of soldering flux and encapsulated water leads to short circuits or resistor-like interconnections between neighboring pads. Water will also damage the sticker and the ink-jet printed text.
- Cleaning with alcohol or other organic solvents can result in soldering flux residues flooding into the two housings, areas that are not accessible for post-wash inspections. The solvent will also damage the sticker and the ink-jet printed text.
- Ultrasonic cleaning will permanently damage the module, in particular the quartz oscillators.

For best results use a "no clean" soldering paste and eliminate the cleaning step after the soldering.

3.2.5 Repeated reflow soldering

Only a single reflow soldering process is encouraged for boards with a LEON-G100/G200 module populated on it. The reason for this is the risk of the module falling off due to high weight in relation to the adhesive properties of the solder.

3.2.6 Wave soldering

Boards with combined through-hole technology (THT) components and surface-mount technology (SMT) devices require wave soldering to solder the THT components. Only a single wave soldering process is encouraged for boards populated with LEON-G100/G200 modules.

3.2.7 Hand soldering

Hand soldering is not recommended.

3.2.8 Rework

The LEON-G100/G200 module can be unsoldered from the baseboard using a hot air gun.

Avoid overheating the module.

After the module is removed, clean the pads before placing.

Never attempt a rework on the module itself, e.g. replacing individual components. Such actions immediately terminate the warranty.

3.2.9 Conformal coating

Certain applications employ a conformal coating of the PCB using HumiSeal® or other related coating products.

These materials affect the HF properties of the LEON-G100/G200 modules and it is important to prevent them from flowing into the module.

The RF shields do not provide 100% protection for the module from coating liquids with low viscosity, therefore care is required in applying the coating.

Conformal Coating of the module will void the warranty.

3.2.10 Casting

If casting is required, use viscose or another type of silicon pottant. The OEM is strongly advised to qualify such processes in combination with the LEON-G100/G200 module before implementing this in the production.

Casting will void the warranty.

3.2.11 Grounding metal covers

Attempts to improve grounding by soldering ground cables, wick or other forms of metal strips directly onto the EMI covers is done at the customer's own risk. The numerous ground pins should be sufficient to provide optimum immunity to interferences and noise.

u-blox makes no warranty for damages to the LEON-G100/G200 module caused by soldering metal cables or any other forms of metal strips directly onto the EMI covers.

3.2.12 Use of ultrasonic processes

Some components on the LEON-G100/G200 module are sensitive to Ultrasonic Waves. Use of any Ultrasonic Processes (cleaning, welding etc.) may cause damage to the module.

u-blox offers no warranty against damages to the LEON-G100/G200 module caused by any Ultrasonic Processes.

4 Product Testing

4.1 u-blox in-series production test

u-blox focuses on high quality for its products. To achieve a high standard it's our philosophy to supply fully tested units. Therefore at the end of the production process, every unit is tested. Defective units are analyzed in detail to improve the production quality.

This is achieved with automatic test equipment, which delivers a detailed test report for each unit. The following measurements are done:

- Digital self-test (Software Download, verification of FLASH firmware, etc.);
- Measurement of voltages and currents;
- Measurement of RF characteristics (e.g. C/No).

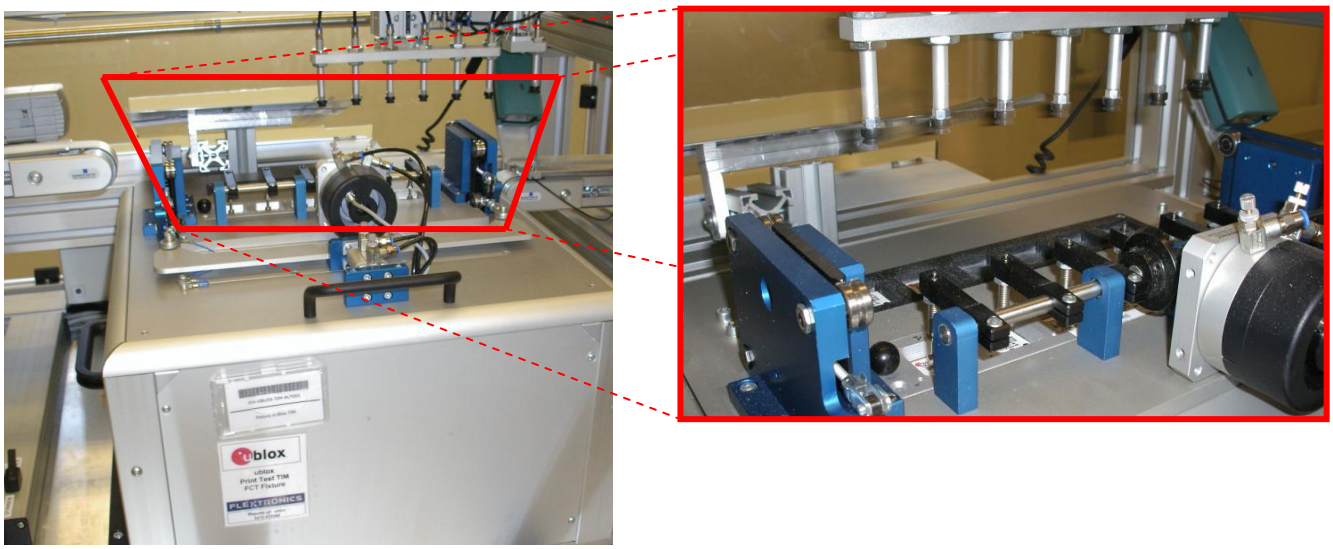

Figure 48: Automatic test equipment for module tests

Appendix

A Extra Features

A.1 Firmware (upgrade) Over AT (FOAT)

Firmware upgrade is available with LEON-G100/G200 modules using AT commands. For more information see the Firmware (upgrade) Over AT (FOAT) Application Note [3].

A.1.1 Overview

This feature allows upgrade the module Firmware over UART, using AT Commands.

- AT Command AT+UFWUPD triggers a reboot and followed by upgrade procedure at specified baud rate (refer to u-blox AT commands manual [2] for more details)
- The Xmodem-1k protocol is used for downloading the new Firmware image via a terminal application
- A special boot loader on the module performs Firmware installation, security verifications and module reboot
- Firmware authenticity verification is performed via a security signature during the download. Firmware is then installed, overwriting the current version. In case of power loss during this phase, the boot loader detects a fault at the next wake-up, and restarts the Firmware download from the Xmodem-1k handshake. After completing the upgrade, the module is reset again and wakes-up in normal boot

A.1.2 FOAT procedure

The application processor must proceed in the following way:

- send through the UART the AT+UFWUPD command, specifying the file type and the desired baud rate
- reconfigure the serial communication at the selected baud rate, without flow control with the Xmodem-1k protocol

send the new FW image via Xmodem-1k.

A.2 Firewall

The feature allows the LEON-G100/G200 user to reject incoming connections originated from IP addresses different from the specified list

A.3 TCP/IP

Via the AT commands it's possible to access the TCP/IP functionalities over the GPRS connection. For more details about AT commands see the u-blox AT Commands Manual [2]

A.3.1 Multiple IP addresses and sockets

Using LEON's built-in TCP/IP or UDP/IP stack, only 1 IP instance (address) is supported. Each IP instance supports up to 16 sockets. Using an external TCP/IP stack (on the application processor), it is possible to have 2 IP instances (addresses).

A.4 FTP

LEON G200 supports via AT commands the File Transfer Protocol functionalities. File are read and stored in the local file system of the module. For more details about AT commands see the u-blox AT Commands Manual [2].

A.5 HTTP

HTTP client is implemented in LEON. HEAD, GET, POST, DELETE and PUT operations are available. The file size to be uploaded / downloaded depends on the free space available in the local file system (FFS) at the moment of the operation. Up to 4 HTTP client contexts to be used simultaneously.

For more details about AT commands see the u-blox AT Commands Manual [2].

A.6 SMTP

LEON supports SMTP client functionalities. It is possible to specify the common parameters (e.g. server data, authentication method, etc.) can be specified, to send an email to a SMTP server. Emails can be send with or without attachment. Attachments are store in the local file system of LEON.

For more details about AT commands see the u-blox AT Commands Manual [2].

A.7 FOTA (LEON-G200 only)

Firmware upgrade over the air (FOTA) is available. For more information see the Firmware (upgrade) Over the Air (FOTA) Application Note [3].

A.8 GPS

The LEON-G100/G200 modules allow a simple and fast connection with the u-blox GPS modules (u-blox 5 family and above). Via the DDC bus it's possible to communicate and exchange data, while the available GPIOs can handle the GPS device power on/off.

For information about implementing u-blox GPS with LEON-G100/G200 modules, including using u-blox' AssistNow Assisted GPS (A-GPS) service see the GPS Integration Application Note [5].

B Glossary

3GPP	3rd Generation Partnership Project
AC	Alternating Current
ADC	Analog to Digital Converter
ADN	Abbreviated Dialing Numbers
AMR	Adaptive Multi Rate
ASIC	Application Specific Integrated Circuit
AT	AT Command Interpreter Software Subsystem, or attention
BB	Baseband
CBCH	Cell Broadcast Channel
CBS	Cell Broadcast Services
CLK	Clock
CMOS	Complementary Metal Oxide Semiconductor
CS	Coding Scheme or Chip Select
CTS	Clear To Send
DAC	Digital Analog Converter
DC	Direct Current
DCD	Data Carrier Detect
DCE	Data Communication Equipment
DCS	Digital Cellular System
DDC	Display Data Channel
DL	Down Link (Reception)
DRX	Discontinuous Reception
DSP	Digital Signal Processing
DSR	Data Set Ready
DTE	Data Terminal Equipment
DTR	Data Terminal Ready
EBU	External Bus Interface Unit
EEP	EEPROM Emulation Parameters
EGSM	Extended GSM
EMC	Electromagnetic Compatibility
EMI	ElectroMagnetic Interference
ESD	Electrostatic Discharge
ESR	Equivalent Series Resistance
FAQ	Frequently Asked Questions
FDN	Fixed Dialing Numbers
FET	Field Effect Transistor
FFS	Flash File System
FIR	Finite Impulse Response
FOAT	Firmware (upgrade) Over AT
FOTA	Firmware Over The Air
FTP	File Transfer Protocol
FW	Firmware
GND	Ground
GPIO	General Purpose Input Output
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HDLC	High Level Data Link Control
HTTP	HyperText Transfer Protocol
I/O	Input / Output
I/Q	In phase and Quadrature
I2C	Inter-Integrated Circuit
I2S	Inter IC Sound
IIR	Infinite Impulse Response
IP	Internet Protocol
ISO	International Organization for Standardization
ITU	International Telecomunication Union

LDN	Last Dialed Numbers
LDO	Low-Dropout
LED	Light Emitting Diode
LNA	Low Noise Amplifier
M2M	Machine to Machine
ME	Mobile Equipment
MIDI	Musical Instrument Digital Interface
MSB	Most Significant Bit
MSD	Moisture Sensitive Devices
MSL	Moisture Sensitivity Level
MUX	Multiplexer or Multiplexed
NOM	Network Operating Mode
NTC	Negative Temperature Coefficient
OSI	Open Systems Interconnection
PA	Power Amplifier
PBCCH	Packet Broadcast Control Channel
PCCCH	Packet Common Control Channel
PC	Personal Computer
PCB	Printed Circuit Board
PCM	Pulse Code Modulation
PCS	Personal Communications Service
PICS	Protocol Implementation Conformance Statement
PIXIT	Protocol Implementation Extra Information for Testing
PMU	Power Management Unit
PPS	Protocol and Parameter Selection
PSRAM	Pseudo Static Random Access Memory
RF	Radio Frequency
RI	Ring Indicator
RoHS	Restriction of Hazardous Substances Directive
RTC	Real Time Clock
RTS	Ready To Send
RX	Receiver
RXD	RX Data
SAR	Specific Absorption Rate
SAW	Surface Acoustic Wave
SCL	Serial Clock
SDA	Serial Data
SDN	Service Dialing Numbers
SIM	Subscriber Identity Module
SMA	SubMiniature version A connector
SMS	Short Message Service
SMTP	Simple Mail Transfer Protocol
STK	SIM Toolkit
SW	Software
TCH	Traffic Channel
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
TS	Technical Specification
TX	Transmitter
TXD	TX Data
UART	Universal Asynchronous Receiver Transmitter
UDP	User Datagram Protocol
UL	Up Link (Transmission)
VCO	Voltage Controlled Oscillator
VSWR	Voltage Standing Wave Ratio
WA	Word Alignment

Related documents

[1] u-blox LEON-G100/G200 Data Sheet, Document No GSM.G1-HW-09001

[2] u-blox AT Commands Manual, Document No GSM.G1-SW-09002

[3] Firmware (upgrade) Over AT (FOAT) Application Note, Document No GSM.G1-CS-09005 (available after 11/09)

[4] Firmware (upgrade) Over the Air (FOTA) Application Note, Document No GSM.G1-CS-09006 (available after 11/09)

[5] GPS Integration Application Note, Document No GSM.G1-CS-09007 (available after 11/09)

[6] ITU-T Recommendation V.24, 02-2000. List of definitions for interchange circuits between data terminal equipment (DTE) and data circuit-terminating equipment (DCE). http://www.itu.int/rec/T-REC-V.24-200002-I/en

[7] 3GPP TS 27.007 - AT command set for User Equipment (UE) (Release 1999)

[8] 3GPP TS 27.005 - Use of Data Terminal Equipment - Data Circuit terminating; Equipment (DTE - DCE) interface for Short Message Service (SMS) and Cell Broadcast Service (CBS) (Release 1999)

[9] 3GPP TS 27.010 - Terminal Equipment to User Equipment (TE-UE) multiplexer protocol (Release 1999)

[10] The I2C-bus specification, Version 2.1, Jan 2000, http://www.nxp.com/acrobat_download/literature/9398/39340011_21.pdf

Part of the documents mentioned above can be downloaded from u-blox web-site (http://www.u-blox.com).

Revision history

Revision	Date	Name	Status / Comments
-	30/04/2009	tgri	Initial release. Objective specification
A	22/06/2009	lpah	New CI
A1	16/07/2009	tgr	Change of document status to advance information
B	20/08/2009	lpah	Figure 1.1 and Figure 1.2: corrected the LEON block diagram Figure 1.17: corrected the SIM Application circuit Document updated for serial port handling Table 1: renamed pins and description Chapter 1.11.1: added the figures related to DSR behavior at power-on, RI behavior at SMS Arrival, RI behavior at incoming call and CTS handling in power saving mode
C	4/011/2009	tgri/lpah/ssesteste/fves	Change of document status to Preliminary. Revision of 2.2.2 footprint and paste mask, 2.2.3 paste mask removed Section 1.5.2completely revised. Added Table 3, updated section 1.5.3.1 Section 1.5.3: added charging temperature range values with clarification Section 1.5.4: added clarification regarding V_BCKP current consumption; added formula to evaluate external capacitor capacitance requirement as function of the buffering time; updated application circuits. Updated Figure 12: Real time clock supply (V_BCKP) application circuits using a 100 µF capacitor to let the RTC run for ~50 seconds at 25°C or using a 70 mF capacitor to let the RTC run for ~10 hours at 25°C when the VCC supply is removed Section 1.6.1: added Figure 14: Power on sequence description Section 1.6.2: added clarification regarding the application circuit to avoid an increase of the module current consumption in power down mode and added the power off sequence diagram Added Figure 15: Power off sequence description Section 1.6.3: added RESET_N equivalent circuit description Updated Figure 16: Application circuits to reset the module using a push button or using an application processor Section 1.9.1.3: clarified and updated application circuit description to connect a handset; added application circuit description to connect an external audio device with analog input/outputs; clarified and updated application circuit description to connect a headset. Added Figure 20. Section1.9.1.5: clarified and updated application circuit description in hands free mode Section 1.9.2: added clarification regarding the application circuit to avoid an increase of the module current consumption in power down mode. Section 1.10: clarified and updated application circuit description for the SIM card. Section 1.11.1: corrected MAX3237 description; added clarification regarding the application circuit to avoid an increase of the module current consumption in power down mode. Section 1.12: clarified as the measured value is input impedance dependent Section 1.13: added clarification regarding the application circuit to avoid an increase of the module current consumption in power down mode. Updated section 2.1: Check UART signals direction, since the signal names follow the ITU-T V.24 Recommendation. Added section 2.3 to explain module thermal resistance. Section 1.11.1: corrected supported UART frame formatCorrected and improved description Updated and improved Figure 3: Power supply concept Added VCC extended and normal operating ranges description and clarified DC power supply requirements in section 1.5.2 Updated and improved Figure 6: Description of the VCC current consumption profile versus time during a GSM call content and caption Clarified current profile description in section 1.5.2.1.2 Updated and improved content and caption Clarified charger requirements in section 1.5.3 Grouped sections Module power on, Module power off, Module reset into the 1.6 System functions chapter Updated and improved Figure 14: Power on sequence description Updated and improved Figure 15: Power off sequence description Clarified Antenna supervisor purpose in the relative section Updated Figure 21: Headset connector application circuit content Clarified I2S PCM mode path in section 1.9.2.1 Updated section 1.11.1: clarified, added and corrected UART features, UART signal behavior, UART application circuits. Updated and improved Figure 27: CTS behavior during normal module operation: the CTS line indicates when the module is able (CTS = ON) or not able (CTS = OFF) to accept data from the DTE and communicate through the UART interface content and caption Updated Figure 26: UART default frame format (8N1) description caption Deleted the double repeated point in the Schematic design-in checklist Clarified pins arrangement in section 2.2.1 Clarified ground plane requirements in section 2.2.1.4 Renumbered sections Antenna termination, Antenna radiation, Antenna detection functionality Corrected AT Commands Manual code in Related documents section Removed “System Configuration“chapter

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